3.0 WATER RESOURCES AND GEOCHEMISTRY

Baseline water quantity and quality in the vicinity of the Goldstrike Mine, Gold Quarry Mine, and Leeville Mine were described in the Betze Project Draft EIS (BLM 1991a) and South Operations Area Project Draft EIS (BLM 1993b). Since these documents were completed, additional water resources and geochemistry information has been collected throughout the project area. Section 3.1, Affected Environment, summarizes baseline conditions relevant to the cumulative impact assessment.

Primary issues addressed in this analysis of cumulative impacts to water resources include the following:

- Reduction in surface and ground water quantity for current users and water-dependent natural resources due to pit dewatering and water management activities.

- Impacts to flow in the Humboldt River from direct mine discharge, mine-induced drawdown and mounding, and projected irrigation withdrawals and return.

- Impacts to surface water quality from mine water management, including impacts to Humboldt River water quality.

- Potential increases in flooding, erosion, and sedimentation associated with water management activities.

- Potential changes in the water balance of the hydrologic study area resulting from the existing and proposed mining activities

The cumulative impact analysis for water resources and geochemistry is subdivided into two primary sections. Section 3.2 describes potential cumulative impacts associated with ground water drawdown and mounding from past, present, and future dewatering activities (and other local water management activities) at the Goldstrike Mine, Gold Quarry Mine, and proposed Leeville Mine located along the Carlin Trend. Section 3.3 describes potential cumulative impacts associated with mine discharges to the Humboldt River. The Humboldt River evaluation considers potential effects between the USGS gage near Carlin and the Humboldt Sink downstream. The analysis considers effects of historic and future discharges from the Goldstrike Mine, Gold Quarry Mine, proposed Leeville Mine, and Lone Tree Mine on flow, water quality, and channel stability.

3.1 Affected Environment

3.1.1 Introduction

3.1.1.1 Study Areas

The Goldstrike Mine, Gold Quarry Mine, and proposed Leeville Mine are located within the Humboldt River Basin in north-central Nevada. The entire Humboldt River Basin covers an area of nearly 17,000 square miles; upstream of the project facilities, the river drainage occupies approximately 7,500 square miles. The Humboldt River flows within an enclosed basin, having no external drainage to a larger flow system. The river flows westward and terminates by evaporation and infiltration in the Humboldt Sink south of Lovelock, Nevada.

For water resources, the affected environment consists of two study areas: 1) a hydrologic study area for mine dewatering (and localized water management activities), and 2) a Humboldt River study area for evaluating potential effects associated with discharge of excess mine water to the river system.

The hydrologic study area for mine dewatering encompasses approximately 2,060 square miles and includes six designated ground water basins established by the Nevada Division of Water Resources (Figure 3-1). These ground water basins, state identification numbers, and land surface areas are listed in Table 3-1. These ground water basins drain southward to the Humboldt River.

The hydrologic study area for mine dewatering is bounded by the Tuscarora Mountains on the north, the Adobe Range and Independence Mountains on the east, and the Humboldt River on the south. As shown in Figure 3-1, the western boundaries of the Willow Creek and Rock Creek ground water basins form the western boundary of the hydrologic study area. Elevations within the study area range from approximately 8,800 feet in the Tuscarora Mountains to 4,500 feet on the Humboldt River near the town of Battle Mountain. The affected environment for the hydrologic study area for mine dewatering is described in Section 3.1.2.

Table 3-1
Major Subregions Within the Hydrologic Study Area

Nevada Designated Ground Water Basin	Basin Number	Approximate Land Area (square miles)
Susie Creek	50	220
Maggie Creek	51	410
Marys Creek	52	60
Boulder Flat	61	560
Rock Creek Valley	62	450
Willow Creek Valley	63	420

Source: State of Nevada 1992; Maurer et al. 1996.

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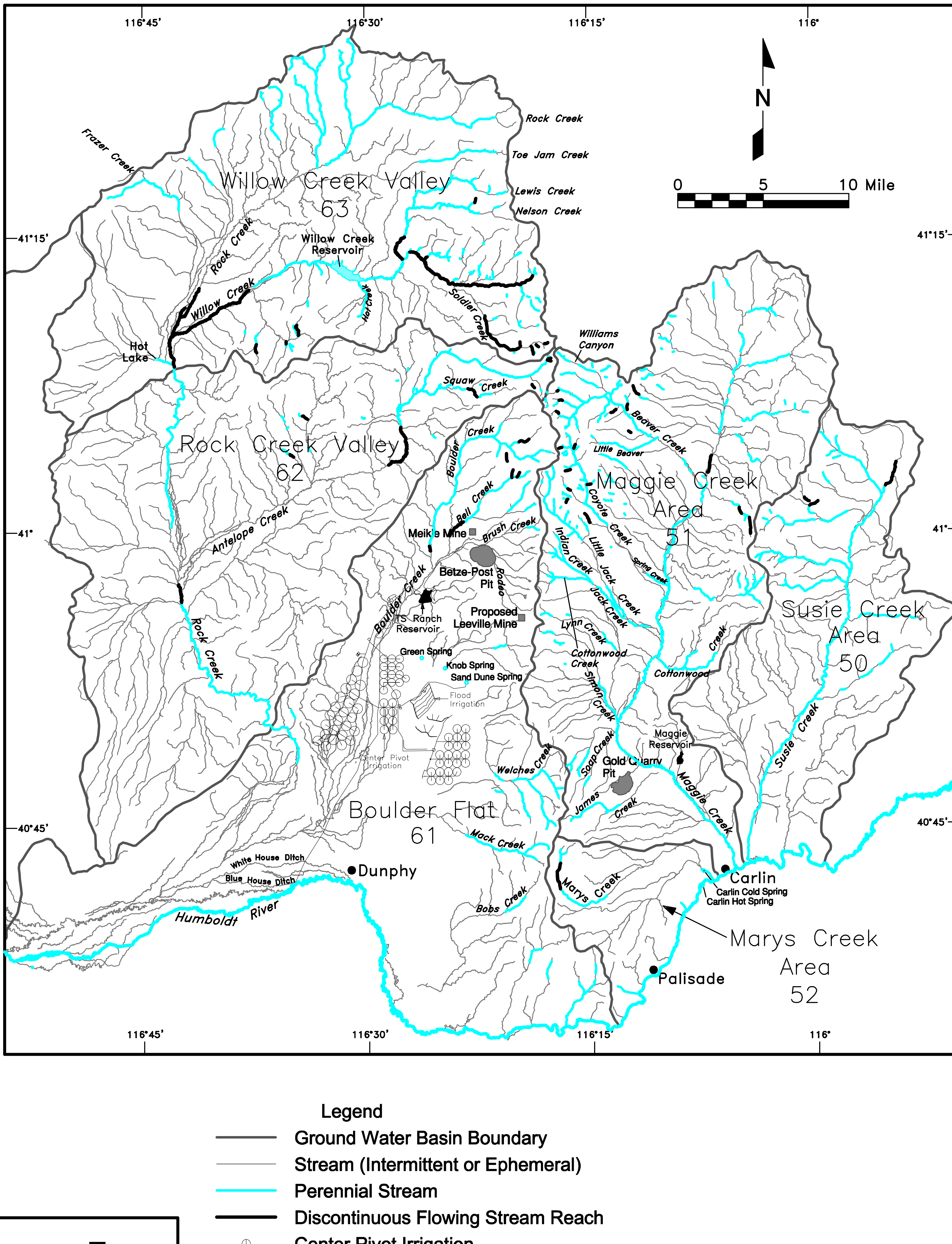

Note: Stream locations are taken from USGS line graph database. Hydrographic Area Boundary locations are approximate.

Figure 3-1

Hydrologic Study Area for Mine Dewatering and Localized Water Management Activities

For the purpose of this study, the streams have been subdivided into three types of reaches that define the general character of the reach: 1) perennial, 2) discontinuous flowing, or 3) intermittent or ephemeral. Perennial stream reaches have some measurable flow year round. Discontinuous flowing stream reaches are characterized as a series of generally short (tens of feet to hundreds of feet in length) perennial segments separated by intermittent segments (defined below). Intermittent segments tend to go dry in late summer to early fall in most years, and ephemeral stream reaches only flow in response to precipitation events. The perennial, discontinuous flowing, and intermittent or ephemeral stream reach segments presented in Figure 3-1 are based on the baseline water resource information presented in AATA International, Inc. 1997, 1998a; JBR 1990a; Newmont 1991, 1992a, 1992b; Nevada Division of Wildlife 1978, 1996b, 1998b; Riverside Technology, inc. (RTi) 1994; and Valdez et al. 1994.

The Humboldt River study area consists of the Humboldt River and its floodplain extending from the USGS gage at Carlin to the Humboldt Sink downstream of Lovelock (Figure 1-1). Quantitative assessments have been conducted for the river from Carlin to the USGS gage at Comus, approximately 9 miles east of Golconda. The Comus gage is approximately 1 mile downstream of the Lone Tree Mine discharge point and reflects the cumulative discharge from the Goldstrike, Gold Quarry, and Lone Tree mines. Semi-quantitative or qualitative assessments have been conducted from Comus to the Humboldt Sink. The affected environment for the Humboldt River study area is described in Section 3.1.3.

3.1.1.2 Hydrometeorology

Average annual precipitation varies widely within the region, but generally increases with elevation (see Figure 4(a) in Plume 1995). Most precipitation falls as snow in the mountains as a result of frontal storms between November and May. Total annual precipitation ranges from 5 to 8 inches on Boulder Flat and 15 to 20 inches at higher elevations in the Tuscarora Mountains. At a weather station near the Betze-Post Pit (at elevation 5,580 feet amsl), the average annual precipitation from 1990 through 1995 was 10 inches. The mean annual snowfall is over 40 inches at places in the Tuscarora Mountains (MMA 1996b). Average monthly precipitation values for approximately 50 years of record at Elko and Battle Mountain are shown in Figure 3-2 (Earthinfo Inc. 1997; National Climatic Data Center 1999). Total annual precipitation has averaged 9.6 inches at Elko and 7.7 inches at Battle Mountain over this period (Table 3-2 and Figure 3-3) (RTi 1998). Precipitation varies along the river, but generally decreases toward the Humboldt Sink. Average annual precipitation is 8.2 inches at Winnemucca and 5.2 inches at Lovelock (National Oceanic and Atmospheric Administration [NOAA] – CIRES 1999).

Table 3-2
Mean Annual Precipitation (inches)

Station	1944 Through 1998	1981 Through 1990	1991 Through 1998	1985 Through 1993
Elko	9.57	9.72	10.20	7.68
Battle Mountain	7.68	7.46	9.88	8.01

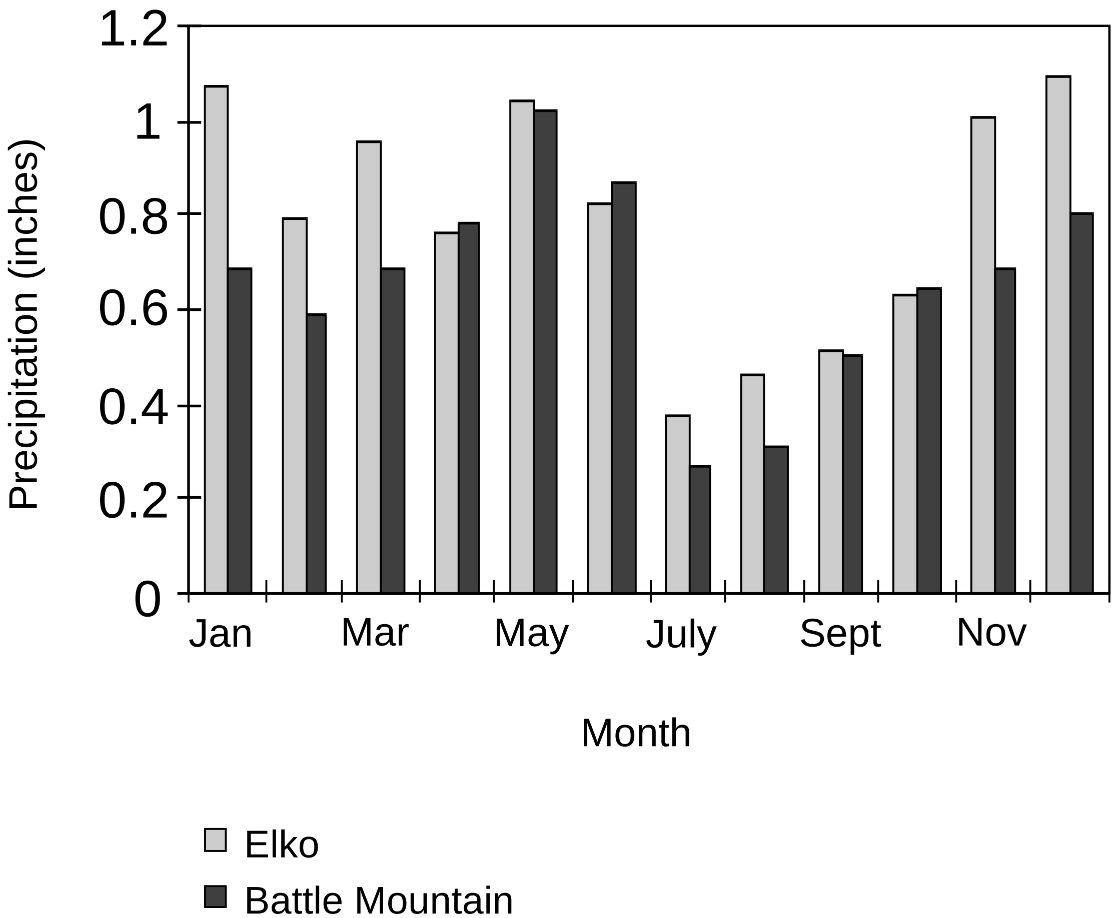

Figure 3-2

Average Monthly Precipitation at Elko and Battle Mountain

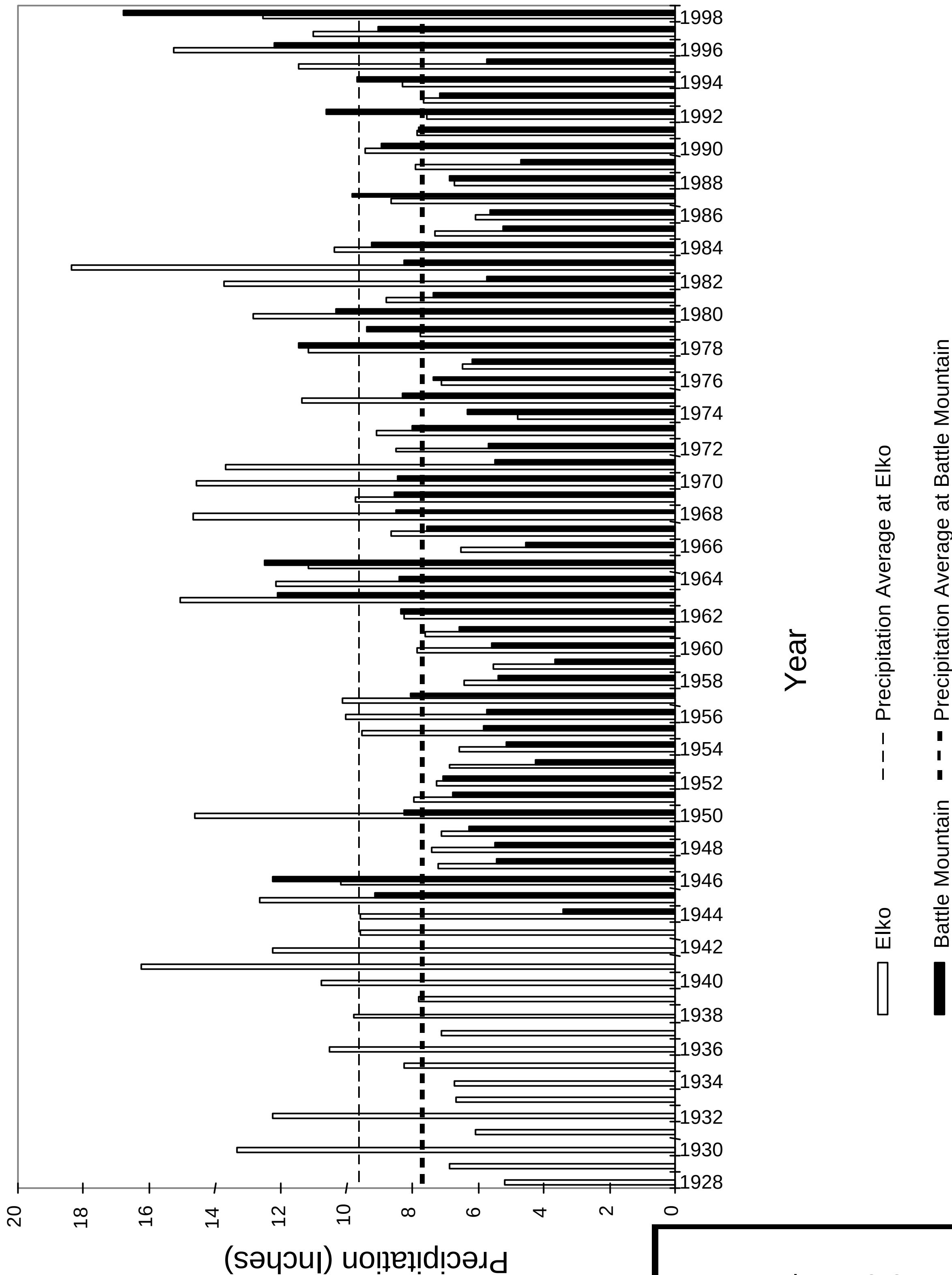

Figure 3-3

Annual Precipitation at
Elko and Battle Mountain

The variation in mean annual precipitation for periods of interest to the surface hydrology analysis is compared to the longer historical record (1944 through 1998) in Table 3-2. A regional drought affected the area between 1985 and 1993 and is most noticeable in the Elko data shown below. Corresponding to this period of less precipitation at higher elevations, the total flow in the Humboldt River at the Carlin gage in 1987 was approximately 40 percent of normal; in 1992, the total flow at the same site was approximately 20 percent of normal (Maurer et al. 1996). In addition to flow effects from less precipitation in the headwaters, irrigation demands during those dryer years reduced flow in the river. Normal or above normal precipitation rates occurred in most areas of Nevada after 1993 (RTi 1998).

High streamflows may occur in the winter or early spring as a result of rain on snow or frozen ground, but more commonly the annual high-flow events occur from snowmelt in the spring. Snowmelt and winter frontal storms can result in sizable runoff volumes and high flood stages over large areas, particularly from rain-on-snow events. Occasionally, isolated flooding may result from intense local thunderstorms, which most often occur from late spring through the fall. These events produce the most intense precipitation in the region, but they are typically limited in duration and extent. As a result, flash floods from thunderstorms generally have larger peak flows than snowmelt events, but they are typically confined to smaller areas and shorter timeframes.

Evaporation, as measured from Class A pan devices, averages about 60 inches per year in the hydrologic study area (NOAA 1982). After accounting for pan characteristics, this converts to a free water surface evaporation rate of about 44 inches per year. This rate approximates the losses that may occur from a shallow lake or slow-moving river. Barrick has collected evaporation data at the Goldstrike Mine from spring to fall since 1990. These partial records also indicate an annual average for pan evaporation of about 60 inches. Evapotranspiration losses vary because of differences in plant species requirements and soil moisture storage. Evapotranspiration is estimated to consume up to 90 percent of the total precipitation in the hydrologic study area (MMA 1996b).

3.1.2 Hydrologic Study Area for Dewatering and Localized Water Management Activities

3.1.2.1 Ground Water

Hydrogeologic investigations have been performed to provide information on existing ground water conditions in the study area. These studies include hydrogeologic investigations that: 1) evaluate potential effects of mine dewatering (ABC 1991, 1992; Balleau Groundwater Consulting and Leggette, Brashears & Graham, Inc. 1992; BLM 1991a; Leggette, Brashears & Graham, Inc. and Balleau Groundwater Consulting 1993; Barrick 1999a; and Newmont 1995); 2) summarize effects of ground water use along the Carlin Trend (Maurer et al. 1996); 3) present a conceptual ground water flow model (MMA 1996a,b, 1997, 1998; and HCI 1999a,b); 4) summarize effects of water use on the Humboldt River (RTi 1998; JBR, 1997; HCI 1997a); 5) report on impacts of Gold Quarry Mine dewatering (Newmont 1992a); and 6) quantify ground water quality and chemistry (Radian International, LLC and Baker Consultants, Inc. 1997a,b; Water Management Consultants 1994; Cohen 1962; Geomega 1997; PTI Environmental Services 1992). These investigations describe baseline information and hydrogeologic conditions of the hydrologic study area for evaluating dewatering impacts.

Recharge, storage, and movement of ground water is dependent in part upon geologic conditions. The general stratigraphic and structural framework throughout the hydrologic study area is described in Chapter 2.0 under Geology and Minerals. The generalized geologic conditions in the region are illustrated in Figures 2-2 and 2-3. Maurer et al. (1996) simplified the complex geology of the region into six hydrostratigraphic units (as described in Section 2.1) that include (from oldest to youngest) marine carbonate rocks, marine clastic rocks, intrusive rocks, volcanic rocks, older basin fill, and younger basin fill.

In bedrock, recharge, storage, flow, and discharge of ground water are largely controlled by the structure (i.e., fault and fracture zones, and solution cavities in carbonate rocks) of the geologic material. In the basin fill alluvium, ground water is stored and transmitted through interconnected pores within consolidated to unconsolidated sediment. In the hydrologic study area, the main aquifers are found in carbonate rocks, volcanic rocks, and basin-fill deposits (Maurer et al. 1996)

Hydrostratigraphic Units

The six hydrostratigraphic units and their hydrogeologic characteristics are discussed below.

Marine Carbonate Rocks. The Paleozoic marine carbonate rocks consist of limestone and dolomite and lesser amounts of shale, sandstone, and quartzite. These rocks are mainly Cambrian to Devonian in age but locally also include Pennsylvanian/Permian carbonate rocks. The western edge of the carbonate rock province is located approximately 6 miles northwest of the Betze-Post Pit. Carbonate rocks appear at the surface in the Tuscarora Mountains south of the Betze-Post Pit and in bedrock outcrops in the Maggie Creek and Susie Creek basins (Figure 2-2). Carbonate rocks are believed to underlie the younger units and the marine clastic rocks (beneath the Roberts Mountain Thrust) in areas within the carbonate rock province. In areas of carbonate rock outcrop, the overlying clastic rocks and younger volcanics have been removed by erosion.

Marine carbonate rocks have low primary permeability. However, where they are faulted or fractured coupled with dissolution, their transmissive properties greatly increase. For example, within the Meikle Mine, caverns with widths greater than 100 feet have been discovered in the carbonate rocks.

Marine Clastic Rocks. The Paleozoic marine clastic rocks consist of interbedded shale, siltstone, chert, quartzite, and limestone. Marine clastic rocks are believed to underlie the alluvium and volcanic rocks in most of the study area, and they form the upper plate of the Roberts Mountain Thrust. They have been mapped mainly as Vinini Formation in the study area. These clastic rocks are exposed in the Tuscarora Mountains, Independence Range, and Adobe Range (Figure 2-2). They have been extensively thrusted and eroded, and estimates of their thickness range from 50 to 5,000 feet.

Intrusive Rocks. Tertiary through Jurassic intrusive rocks are a minor component of the rock types in the study area (Figure 2-2) and consist mostly of granodiorite, quartz monzonite, monzonite, and diorite. The intrusive rocks form a relatively impermeable boundary immediately south of the Betze-Post Pit. They also mark the southern boundary of mineralization in the mine area. These rocks have relatively low hydraulic conductivity, and wells completed in the intrusive rocks may yield small quantities of water near some faults (Maurer et al. 1996), generally less than 10 gallons per minute (gpm) (MMA 1996b).

Volcanic Rocks. Tertiary through Jurassic volcanic rocks consist of a wide range of igneous rock types: rhyolitic to basaltic lava flows, welded and nonwelded ash-fall tuffs, flow breccia, and tuffaceous sedimentary rocks. The volcanics occur throughout the area with most of the exposures in the western, northern, and south-central portions of the hydrologic study area (Figure 2-2). This wide range of rock types results in highly variable hydraulic parameters. The welded tuff, basalt, and andesite generally have low transmissive properties, while the rhyolite, particularly where fractured, is more transmissive.

Older Basin-Fill Deposits. Pilocene to Miocene age basin-fill deposits in the area are primarily composed of poorly consolidated shale, claystone, mudstone, siltstone, sandstone, conglomerate, freshwater limestone, tuff and lava flows (Plume 1995; Maurer et al. 1996). These deposits accumulated in basins that developed in the earliest stages of extensional faulting. In the upper Maggie Creek Basin, these deposits are estimated to be up to 6,000 feet thick. In Susie Creek and lower Maggie Creek basins, the deposits are generally less than 2,000 feet thick (HCI 1999b). Wells completed in the Carlin Formation have reported yields ranging from less than 100 to 1,000 gpm. In the Maggie Creek area, hydraulic conductivity ranges from 1 to 7 feet/day and transmissivity from 780 to 9,800 square feet/day (Maurer et al. 1996). In the northern part of Boulder Flat, transmissivity is estimated to range from 70 to 300 square feet/day (Stone et al. 1991). Locally, the fine-grained beds act as an aquitard producing confined ground water conditions in the underlying rocks (BLM 1991a).

Younger Basin-Fill Deposits. The Quaternary alluvium contains a wide range of materials: sandy clay, silty sand, gravelly sand, and sandy gravel. The thickness and lateral extent of this material is also highly variable. In higher elevation mountain areas, the alluvium occurs as discontinuous to continuous strands of unconsolidated material covering or partially covering bedrock along the floor of the valley or ravine. Alluvium in higher elevation areas is generally less than a few tens of feet thick. In broad basin areas, such as Boulder Flat, and to a lesser extent in the Maggie Creek and Susie Creek basins, the alluvium occurs as sequences of unconsolidated to poorly consolidated material up to 1,600 feet thick (Maurer et al. 1996). Overall, the alluvium is generally coarser-grained in the mountains and finer-grained in the basins, and it becomes finer toward the center of the basin. The alluvium also is characterized by significant lateral and vertical stratigraphic variation with clay typically occurring as thinly bedded lenses. The alluvium is generally presumed to be an unconfined aquifer; however, semi-confined conditions may exist locally where less permeable fine-grained units inhibit vertical flow. Hydraulic conductivity in the younger basin fill material ranges widely (Maurer et al. 1996).

Hydrostructural Units

Ground water flow pathways are influenced by major faults that offset and displace rock units and older alluvial deposits. Depending on the physical properties of the rocks involved, faulting may either result in the fault zone behaving as an impediment or a conduit for ground water flow relative to the surrounding hydrostratigraphic units. For example, faulting of softer, less competent rocks typically forms zones of crushed and pulverized rock material that tend to impede or reduce ground water movement across the fault zone. In addition, faulting may impede flow by juxtaposing rocks with relatively low permeabilities against rocks with much higher permeabilities. In contrast, faulting of hard, competent rocks often creates conduits along the fault trace resulting in zones of higher ground water flow and storage capacity compared to the unfaulted surrounding rock. Depending on the rock materials and type of fault movement, it is possible for the fault to act as both an impediment to flow across the fault and a conduit to flow along the strike of the fault.

Long-term monitoring of drawdown and mounding in the vicinity of the Goldstrike property has resulted in the recognition of three major faults or fault zones that tend to impede the movement of ground water across the faults. These faults include the 1) Boulder Narrows Fault located in Boulder Valley; 2) Siphon Fault located between the TS Ranch Reservoir and the Betze-Post Pit; and 3) Post Fault located on the east side of the Betze-Post Pit. The locations and descriptions of these major hydrostructural features are presented in Appendix D, Section D1.1.4.

Hydrologically significant faults identified in the vicinity of the Gold Quarry Mine and within the six-basin study area, include the following: Tuscarora, Castle Reef, Soap Creek, Range Front, Genesis, Four Corners, Basin Bounding, Hardie, Leeville, Chukar Gulch, GPX, Gray/Challenger, Maggie Creek, and Sheep Creek faults (HCI 1999b). The locations and estimates of hydraulic parameters for these faults are presented in Appendix D, Section D2.1.7.

Geothermal System

A deep geothermal system exists in the carbonate aquifer in the vicinity of the Betze-Post Pit and Meikle Mine. High-yield wells located within the carbonate aquifer compartment (that extends from the Betze-Post Pit to a distance of approximately 6 miles northwest of the Betze-Post Pit) have reported temperatures at the well head of 140 to 145 degrees Fahrenheit (°F). In contrast, wells drilled into the low-yield, marine clastic rocks located immediately east of the Betze-Post Pit have well-head temperatures that range from 70 to 90°F. Identification and understanding of the deep geothermal system is important to understand the movement of ground water. For specific hydraulic characteristics and head distributions, the rate of flow of ground water increases with increasing temperature (or, conversely, decreases with decreasing temperature) (MMA 1998). However, to date the temperature of the dewatering water has been relatively constant throughout the life of the mine; therefore, significant flow changes resulting from changing water temperatures are not anticipated.

Ground Water Levels

Premining (Prior to 1991). Limited data exist to define the premining ground water elevation (or potentiometric surface) throughout the region. Unconfined ground water levels in the hydrologic study area prior to active mine dewatering are presented in Figure 3-4. These unconfined water levels are based on water levels recorded in wells in the Boulder Flat area in 1990 and in the Maggie Creek area in 1988 (Maurer et al. 1996). According to this evaluation, the elevation of the potentiometric surface ranged from

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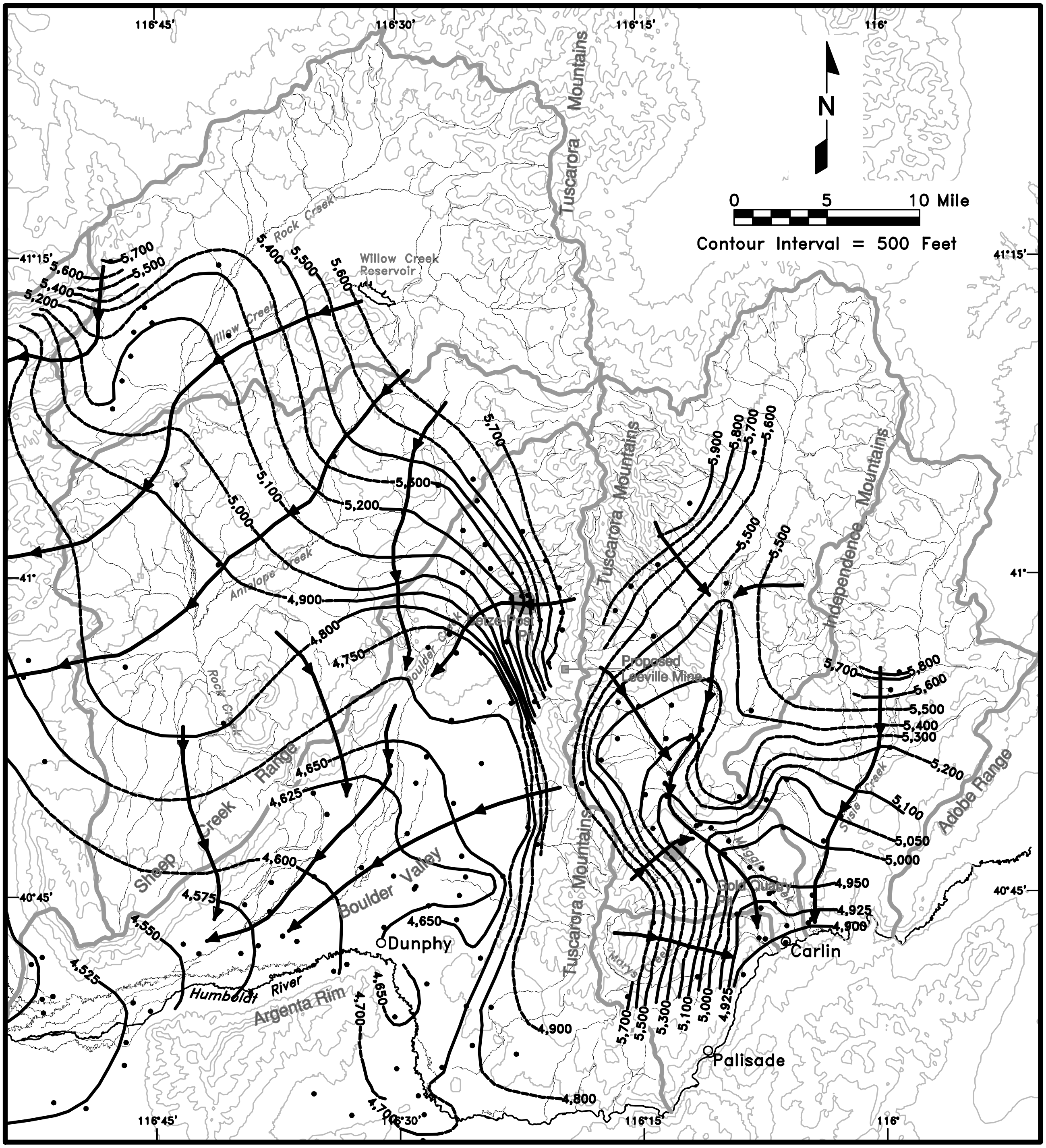

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Ground Water Basin Boundary

Stream

Water-table contour, dashed where uncertain

General Direction of Ground Water Flow

Wells

Figure 3-4

Unconfined Ground Water Levels, 1990-1991 over 5,700 feet amsl on the western flank of the Tuscarora Mountains, to less than 4,600 feet amsl in the lower part of Boulder Flat, to over 5,900 feet amsl on the eastern flank of the Tuscarora Mountains, and to approximately 4,900 feet amsl adjacent to the Humboldt River near Carlin.

As illustrated in Figure 3-4, the general, inferred direction of ground water flow is away from the crest of the bedrock mountain blocks toward the basin fill deposits. The Tuscarora Mountains function as a ground water divide separating flow systems west of the divide from the flow system east of the divide. West of the divide, ground water in Willow Creek Valley, Rock Creek Valley, and Boulder Flat flows west out of the hydrologic study area and southwest toward the Humboldt River. East of the divide, ground water in the Maggie Creek, Marys Creek, and Susie Creek areas flows south toward the Humboldt River.

Water Balance

Estimates of ground water inflow and outflow for the Willow Creek, Rock Creek, Boulder Valley, Maggie Creek, Marys Creek, and Susie Creek ground water basins under premining (prior to major mine dewatering) conditions are summarized in Table 3-3. Precipitation is the ultimate source of recharge to the ground water system. A percentage of the precipitation falling in the higher elevation mountains returns to the atmosphere essentially where it falls. The remainder infiltrates the bedrock where it falls or runs off and then either infiltrates the ground water system through the bottom of the stream channel or leaves the basin as surface flow. Runoff is channelized in the mountains and then tends to rapidly infiltrate the course-grained alluvial fan as the stream channel emerges from the mountains. This type of recharge, referred to as mountain front recharge, is believed to be the primary recharge source for the basin-fill alluvial aquifers. In the lower portions of the basins, negligible recharge is expected to occur from direct infiltration of precipitation, but some infiltration does occur in irrigated areas.

The total recharge to the hydrologic study area is an estimated 82,000 acre-feet/year. This estimate includes 47,000 acre-feet/year received in the Willow Creek, Rock Creek, and Boulder Valley basin areas in the western portion, and approximately 35,000 acre-feet/year received in the Maggie Creek, Marys Creek, and Susie Creek basin areas in the eastern portion of the hydrologic study area.

In Boulder Flat, an estimated 29,000 to 40,000 acre-feet/year of ground water inflow occurs from infiltration of Humboldt River water. An additional 600 acre-feet/year of ground water inflow to Boulder Flat is estimated to occur from subsurface ground water flow from adjacent basins south of Boulder Flat.

Discharge from the bedrock and alluvial basin-fill aquifers occurs through evapotranspiration, ground water flow leaving the basins as subsurface outflow, discharge to streams and springs, and ground water pumping. Evapotranspiration accounts for an estimated 79,000 acre-feet/year (Maurer et al. 1996) of ground water outflow from the hydrologic study area. West of the Tuscarora Mountains, in the Willow Creek, Rock Creek, and Boulder Flat basins, an estimated 19,000 acre-feet/year of ground water outflow occurs as flow into the Clovers area located west of the hydrologic study area. An estimated 8,600 acre-feet/year of ground water discharge occurs from the Maggie Creek, Marys Creek, and Susie Creek areas to the Humboldt River; an additional 3,400 acre-feet/year of ground water discharge occurs as spring flow at Carlin Springs and another nearby unnamed spring in the Marys Creek Basin (Maurer et al. 1996).

Table 3-3
Pre-1991 Estimated Ground Water Budget
(Published and Unpublished Estimates of Water Budget Components for the Willow Creek, Rock Creek, Boulder Flat, Maggie Creek, Susie Creek, Marys Creek, and Rock Creek Ground Water Basins
[acre-feet/year])

Budget Component	Willow Creek Basin	Rock Creek Basin	Boulder Flat Basin	Maggie Creek Basin	Marys Creek Basin	Susie Creek Basin
GROUND WATER INFLOW						
Recharge (Total)	20,000[1]	13,000[3]	14,000[3]	23,000[3]	2,100[3]	9,700[3]
Direct	14,000[2]	9,800[1]	19,300[1]	16,000[4] -13,900[1]		
Mountain Front		6,000[1]	11,200[1]	20,200[1]		
Subsurface Inflow			600[3]			
Infiltration from Rivers and Streams	0	0[1]	40,000[3]	0[1]	0	0
Humboldt		20,000[1]	29,000[1]	0[1]		
Others						
GROUND WATER OUTFLOW						
Evapotranspiration	9,000[3]	4,600[3]	30,000[3]-51,000[3]	5,434[4] - 11,000[3]	2,000[3]	1,700[3]
Subsurface Outflow	4,300[3]	2,800[3]	12,000[3]	0[3]	0[3]	0[3]
Discharge to:						
Humboldt River	0[3]	0[3]	0[3]	5,700[5]	500[6]	2,400[6]
Rivers, Streams						
Springs					3,400[3]	
Pumpage			3,000[1]	244[5]		
SURFACE WATER OUTFLOW (at Basin Outlet)	N/A	29,000[2]	N/A	18,000[3]	4,200[2]	9,500[3]

[1]Maurer et al. 1996.
[2]MMA 1998.
[3]Nevada State Engineer's Office 1971a, b.
[4]Plume and Stone 1992.
[5]Total ground water discharge from Susie Creek, Maggie Creek, and Marys Creek areas was estimated at 8,600 ac-ft/year by Maurer et al. (1996); this total was divided among the three areas in proportion to the recharge reported in Maurer et al. (1996).
[6]MMA 1996b, 1997.
N/A = No estimates available.
ET = Evapotranspiration.

Ground Water Rights

According to the records, a total of 234 ground water rights and applications for ground water rights are recorded within the hydrologic study area. Information on these rights and applications for rights is summarized in Appendix A, Table A-1; the point of diversion locations listed for the water right or application for water right are shown in Figure 3-5 (Nevada State Engineer's Office 1999, 2000). This inventory does not include rights and applications for rights owned by Barrick or Newmont that are classified as mining and milling. Since water rights are not necessary for most domestic wells, this inventory (based on information on file at the NDWR) does not include all domestic or stock watering wells that may exist within the regional study area. However, included in Table A-1 are five known water supply wells that are apparently used for domestic or stock watering and that do not have a water rights permit or application number. Other domestic water supply wells that are not included in this inventory likely exist in the vicinity of Carlin in the southeastern portion of the hydrologic study area.

Seeps and Springs

A series of field investigations have been performed to identify perennial seeps and springs located within the region surrounding the Goldstrike and Gold Quarry mines. All identified springs within the hydrologic study area are shown in Figure 3-6 (JBR 1990a; RTi 1994; JBR 1992b; Newmont 1999c; MMA 1998; USGS quads). Two field investigations have been conducted to identify perennial seeps and springs located within the region surrounding the Goldstrike Mine. Both inventories were conducted in the fall in order to identify springs with perennial flow that represent discharge from the ground water system. The first inventory was conducted by JBR in the fall of 1989 (JBR 1990a) to identify all seeps and springs located within an approximately 10-mile radius of the Betze-Post Pit. The JBR inventory included Boulder, Bell, Brush, and Rodeo Creek watershed areas. The JBR study identified 131 seeps and springs as summarized in the Betze Project Draft EIS (BLM 1991a). The second inventory was conducted by RTi in the fall of 1993 (RTi 1994) and extended the area of coverage to approximately 600 square miles. This area included the Willow Creek, Rock Creek, and Antelope Creek watersheds, and springs located in the north, south, and eastern portions of the Tuscarora Mountains. The RTi (1994) inventory identified an additional 277 seeps and springs with perceivable flows and 211 seeps with no perceivable flow. The locations of all of the identified seeps and springs are presented in Figure 3-6. In the hydrologic study area, the springs that were not inventoried by RTi, JBR, or Newmont Gold Company were digitized from the USGS 7.5-minute quadrangles. Springs are not evenly distributed throughout the area; they discharge throughout the Tuscarora Mountains and occur as clusters in the upper and lower Willow Creek area, upper Antelope Creek-Squaw Creek area, and east of the Tuscarora Mountains. Conversely, there are large areas in the Sheep Creek Range-Rock Creek area and lower Boulder Creek-Boulder Valley area that are devoid of identified natural springs.

Flows for all springs identified in the region surrounding the Goldstrike Mine area ranged from less than 1 gpm to 140 gpm, with most springs having discharges of less than 3 gpm. In this area, the flow rate measured in the fall, or low-flow season, ranged from less than 1 gpm up to approximately 3 gpm for approximately 90 percent of the springs. Only four inventoried springs had flows greater than 10 gpm. On the east slope of the Tuscarora Mountains (region east, southeast, and northeast of the Betze-Post Pit) there are numerous springs. The majority of these springs are located at higher elevations (greater than

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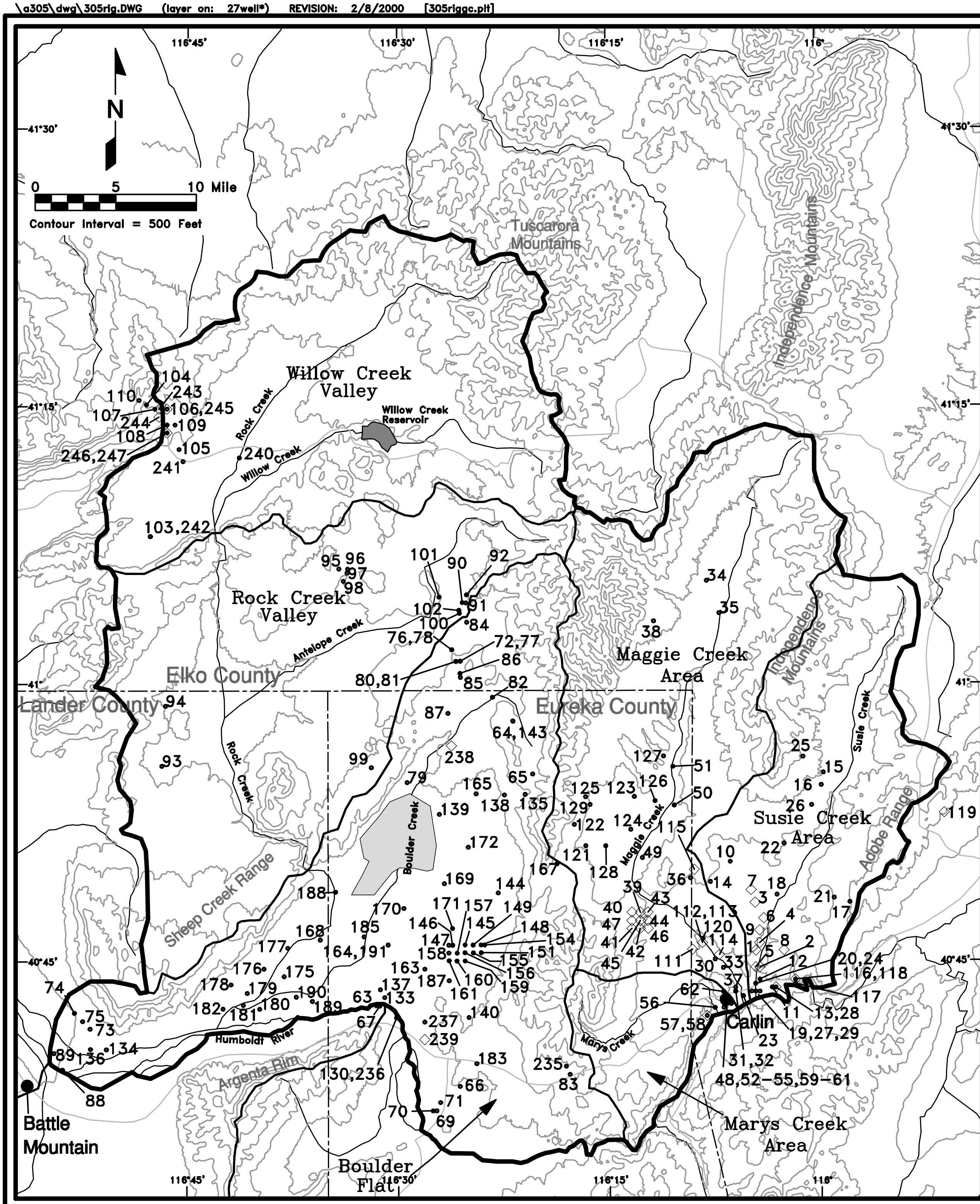

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Study Area

Ground Water Basin Boundary

Stream

County

70 Point of Diversion for Ground Water Right with Current Permit, Certificate, or Vested Status

47 Listed Point of Diversion for Applications for Ground Water Right (Application, Ready for Action, and Ready for Action Protested), and other known well locations

This area contains 54 ground water rights and application for ground water rights (Numbers 68, 131, 132, 141, 142, 150, 152 153, 162, 166, 173, 174, 184 186, 192-215, and 218-233). The point of diversion locations are provided in Table A-1.

See Table A-1 for details

Figure 3-5

Ground Water Rights, Application for Ground Water Rights, and Other Known Wells in the Hydrologic Study Area

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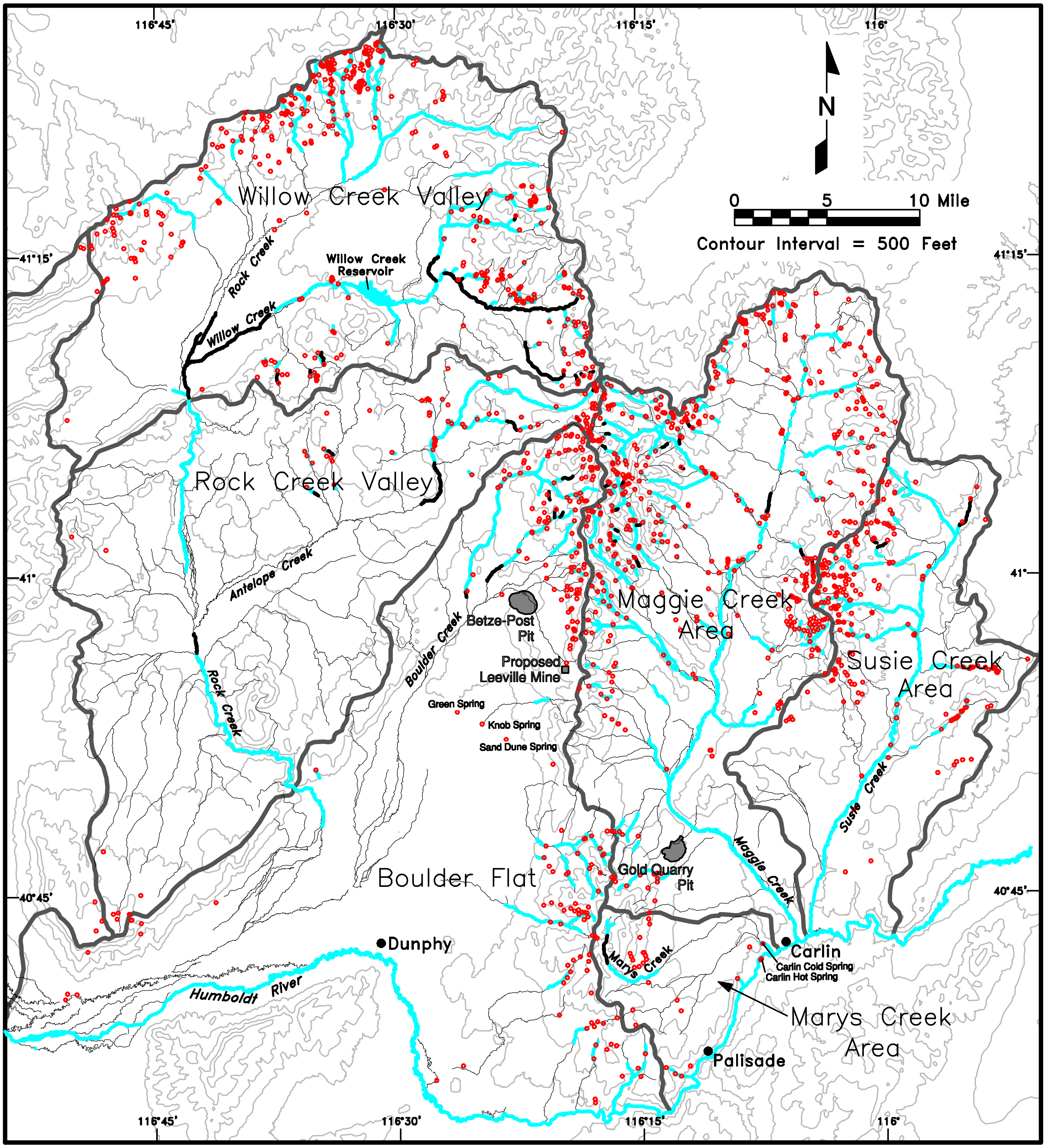

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Ground Water Basin Boundary

Stream (Intermittent or Ephemeral)

Perennial Steam

Discontinuous Flowing Stream Reach

Spring and Seeps

Note: Stream locations are taken from USGS line graph database. Hydrographic Area Boundary locations are approximate.

Figure 3-6

Areas of Perennial Stream Reaches, Springs, and Seeps in the Hydrologic Study Area

6,500 feet). Flow rates for these springs show a similar pattern to springs on the west slope of the Tuscarora Mountains with most having low-flow rates (less than 3 gpm). However, a few larger springs occur with flow rates of over 10 gpm.

Several seep and spring studies have been conducted in the region surrounding the Gold Quarry Mine. JBR (1992b) conducted a comprehensive spring and seep inventory in May and June 1992 that identified approximately 200 springs and seeps in this region. Of these, approximately 75 representative springs located within a 10-mile radius of the Gold Quarry Mine have been monitored biannually since 1990 (Newmont 1999c).

Within a 10-mile radius of the Gold Quarry Mine, the majority of inventoried springs and seeps have flow rates of less than 5 gpm. Of the 75 springs measured by Newmont, 14 had average October flows between 5 and 50 gpm; only 5 springs had average October flows greater than 50 gpm (Newmont 1999c). Seasonal variations in flow occur in a number of springs, indicating shallow perched systems where flow is easily influenced by seasonal precipitation.

For springs inventoried in the northern portion of the Tuscarora Range, and Boulder Flat, Rock Creek, and Willow Creek Hydrographic Basins, the measured temperature of the springs ranged from 38 to 78°F. Since most of the springs have very small flows (less than 3 gpm), the measured temperature is strongly influenced by air temperature. No hot (greater than 90°F) springs were identified during the inventories for these areas (JBR 1990a; RTi 1994). For springs inventoried in the Maggie Creek, Marys Creek, and Susie Creek Hydrographic Areas, three hot springs and one warm spring have been identified (Newmont Spring Nos. 24, 40, 43, and 52). One hot spring (Spring 24) is located in the Susie Creek Hydrographic Basin, and two hot springs (Springs 40 and 43 located along the Humboldt River) and one warm spring (Spring 52) are located in the Marys Creek Hydrographic Basin. Spring 24 consists of a series of small springs with combined flow rates of approximately 25 gpm. Spring 40 is a small spring with October flow rates less than 1 gpm. Spring 43, also known as Carlin Hot Springs, flows directly into the Humboldt River. Spring 52 is a warm spring with average temperatures near 68°F and flows above 500 gpm.

3.1.2.2 Surface Water

Surface Water Flows and Channel Characteristics

Surface water flows in the hydrologic study area originate from snowmelt, infrequent rainfall events, and ground water discharge from springs and seeps. A number of stream channels occur in the study area (Figure 3-1), and they all flow toward the Humboldt River. On the eastern side of the Tuscarora Mountains, Marys Creek, Maggie Creek, and Susie Creek flow directly into the Humboldt River. These three drainages have been investigated by Newmont (1991), Maurer, et al. (1996), and Zimmerman (1992a). On the west side of the Tuscarora Mountains, Rock Creek forms the major tributary to the Humboldt River. Willow Creek and Antelope Creek are major tributaries to Rock Creek to the north and west of Barrick's operations. Rock Creek traverses the southwest portion of Boulder Flat and receives flow from Blue House Slough as well as the Boulder Creek - White House Ditch - Blue House Ditch system before it joins the Humboldt River near Battle Mountain. Smaller drainages such as Rodeo Creek, Brush Creek, and Bell Creek occur in closer proximity to the Goldstrike property and form tributaries to Boulder Creek. The locations of surface water monitoring sites are shown in Figure 3-7 (Barrick 1999a; Maurer et al. 1996; Newmont 1999d).

Many streams in arid climates have short perennial or intermittent reaches near their headwaters or in narrow rocky canyons where channel conditions are restricted by bedrock near the surface; this generally holds true in the hydrologic study area. Perennial reaches for streams in the hydrologic study area have been identified through field surveys (RTi 1994; AATA 1998a,b; Newmont 1999e). These reaches are shown in Figure 3-1 and generally occur in remote locations above the most upstream stations in the monitoring program. As such streams flow downstream onto deeper unconsolidated deposits such as alluvial fans, they commonly lose large amounts of flow to seepage into the channel bed. During most years, flow occurrence in these downstream alluvial reaches may be intermittent or ephemeral. This is demonstrated by most of the streams in the project area, where flows often cease during the last half of the year. The major exception to this is Rock Creek, which has both intermittent and perennial reaches interspersed along its length.

Flow data for selected Boulder Valley streams prior to dewatering activities is available for the Betze Project EIS (BLM 1991a,b). These data indicate that Rodeo Creek was ephemeral in its uppermost reach (approximately one-third of its overall length), but flowed perennially because of springflow contributions immediately downstream. Proceeding downstream, the creek flowed during a substantial part of the year, but flows diminished or ceased in late summer and fall. The stream was intermittent to ephemeral in the lower third of its length above Boulder Creek. The short perennial reaches interspersed along Rodeo Creek were largely a result of springflows along the channel.

According to the earlier baseline information (1988 through 1990), Bell Creek flowed perennially in its upper reaches, becoming intermittent approximately 2 miles above its confluence with Rodeo Creek. Subsurface flow maintained perennial pools that were observed over a short section of the lower intermittent reach. Brush Creek was perennial in its upper headwater reach and along its middle reach on the valley alluvium. It became ephemeral downstream approximately 1 mile above its confluence with Rodeo Creek. Boulder Creek was perennial in its upper headwater reaches, primarily because of springflow contributions. Flows became ephemeral approximately 1 mile above the confluence with Rodeo Creek and remained so downstream (BLM 1991a,b).

Based on recent data from the Boulder Valley Monitoring Plan (Barrick 1999a), Boulder Creek appears to be a predominantly losing stream (flow seeping from the channel to ground water recharge) in the vicinity of Barrick's operations during both high-flow and low-flow seasons. The stream is perennial in its uppermost reaches and intermittent in the vicinity of the Goldstrike property. Significant decreases in streamflow occur as Boulder Creek leaves its canyon headwaters and moves onto the valley alluvium in the vicinity of Barrick's treatment facilities. Downstream of Barrick's mining and processing operations, Boulder Creek is an ephemeral channel; based on records since 1991, it flows only in response to snowmelt or the occasional local thunderstorm. Rodeo Creek appears to lose flow in spite of its increasing watershed area until it is joined by Bell Creek. Below that confluence, Rodeo Creek flows substantially increase due to contributions from Bell Creek, but slight seepage losses to the alluvium may occur. Brush Creek flows do not exhibit a consistent pattern of losses or gains.

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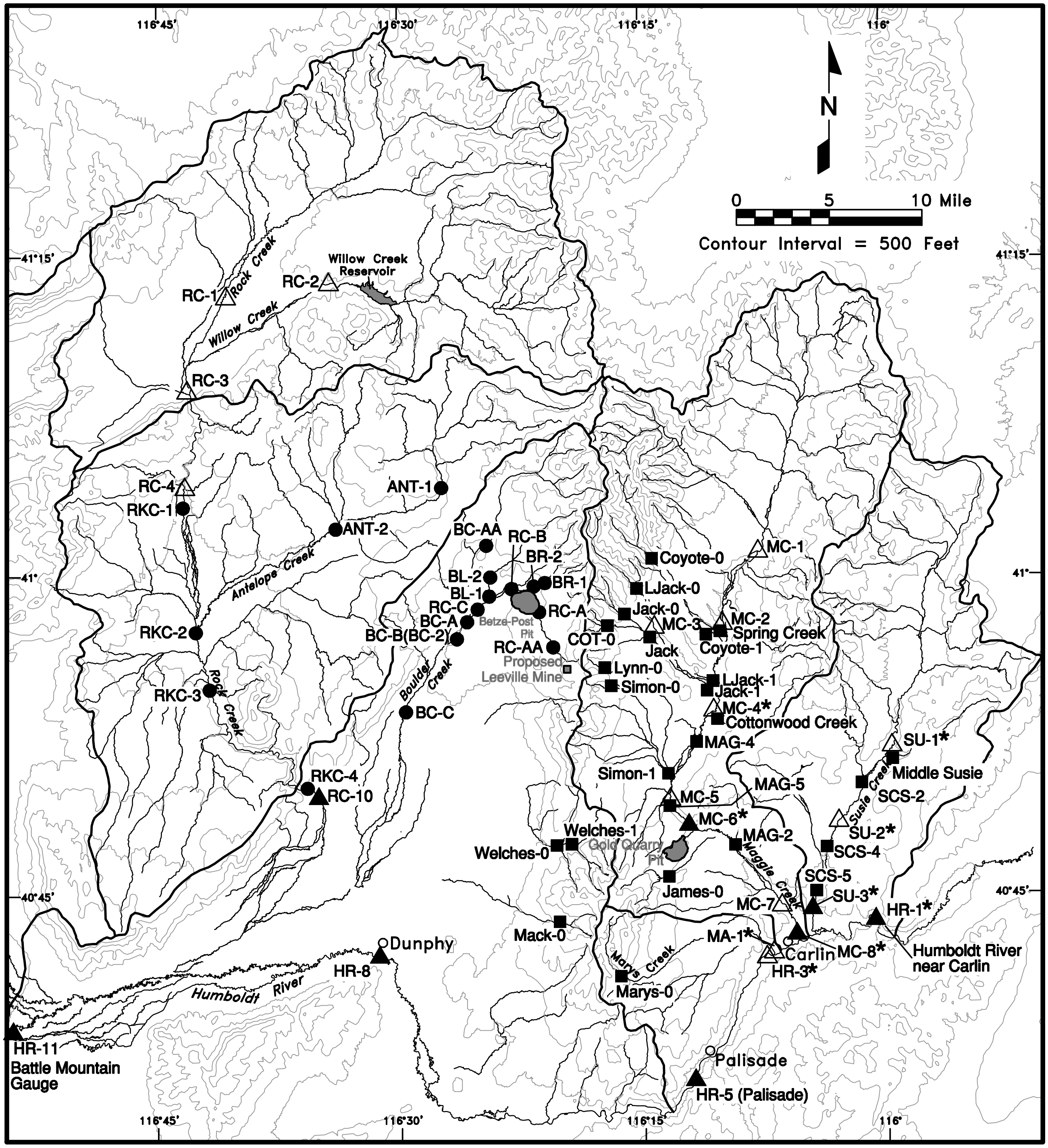

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- Ground Water Basin Boundary
- Stream
- HR-1 ▲ USGS Active Streamflow Site ①
- MC-7 △ Former USGS Streamflow Site ①
- BC-C ● Barrick Surface Water Sampling Location ②
- ■ Mack-0 Newmont Surface Water Sampling Location ③

Notes: *Streamflow measurement site also monitored by Newmont

Abbreviations:

① USGS:
HR = Humboldt River; MC = Maggie Creek; BC = Boulder Creek; RC = Rock Creek and its tributaries

② Barrick:
ANT = Antelope Creek; BC = Boulder Creek; BL = Bell Creek; BR = Brush Ceek; and RKC = Rock Creek

③ Newmont:
MAG = Maggie Creek; and SCS = Susie Creek

Figure 3-7

Streamflow Measurement Sites, Humboldt River Tributaries

Antelope Creek data for 1996 and 1997 do not indicate a discernible pattern of losses or gains, but it is probable that some flow was lost to recharge to valley alluvium along the middle and lower reaches. During the low-flow season in 1993, the upper reaches of Antelope Creek and Squaw Creek (located 5 to 7 miles north of the Betze-Post Pit) exhibited flows of 15 to 20 gpm (RTi 1994). Although flows that year were 50 to 70 percent higher than average regionally, these suggest that perennial flows exist on these streams in the locale. These stream reaches are shown in Figure 3-6. Approximately 4 miles below its headwater springs, Antelope Creek had flows of approximately 15 gpm. Below this point, gaining and losing reaches alternated over short distances depending on springflow contributions and channel seepage. On September 30, 1993, Squaw Creek at its mouth contributed approximately 20 gpm to Antelope Creek, but a short distance downstream the latter was flowing at only 17 gpm. Approximately 2.5 miles farther downstream, Antelope Creek flowed at 22 gpm. Another 3.5 miles farther downstream, the stream was dry (RTi 1994).

This last location approximates the most upstream monitoring station (ANT-1) for Antelope Creek in the Boulder Valley Monitoring Plan. The location of this station also is known as RC-6 (designation per Maurer et al. 1996). Data in the Boulder Valley Monitoring Plan through 1998 also indicate that Antelope Creek goes dry at this location during the late summer. Maurer et al. (1996) indicate that Antelope Creek is predominantly an ephemeral stream along its length, except for short reaches sustained by small ground water baseflows.

Rock Creek and its tributary, Willow Creek, are the principal streams in Willow Creek Valley northwest of Barrick's operations. Streamflows in both Willow Creek and Rock Creek downstream of their confluence are affected by irrigation diversions and releases from Willow Creek Reservoir. Both gaining and losing measurements were made in this area, but typically these upper reaches are probably gaining flows from ground water contributions (Maurer et al. 1996). Also, in the upper reaches of Rock Creek, near its confluence with Willow Creek, a discharge location known as Hot Lake occurs near where Rock Creek leaves Squaw Valley. This feature is a major discharge area that supplies most of the water in Rock Creek in the vicinity during low-flow periods. The name Hot Lake is misleading because the water is similar in temperature to other flows in the area, which have normal surface water temperatures. Examination of the topography in the south end of Squaw Valley suggests that it is possible for the water in Rock Creek and the irrigated agricultural areas northeast of Hot Lake to move in the alluvium until a subsurface barrier is encountered near the hills in the vicinity of the lake. Such a barrier could force water to surface at Hot Lake. The flow may be a combination of water from Willow Creek, Rock Creek, and other watersheds in the area.

In 1996 through 1998, Rock Creek exhibited both baseflow gaining (flow returning to the channel from ground water contributions) and losing reaches along its length. North of the Sheep Creek Range, the stream lost flow during the low-flow season as it traversed the Rock Creek Valley alluvium. In 1996 and 1997, it slightly regained baseflow while passing through the Sheep Creek Range and also received additional peak flow contributions in the spring from higher elevation watersheds in this locale. This somewhat differs from earlier data summarized by Maurer et al. (1996), which found that Rock Creek gained ground water flows within lower Rock Creek (above the Sheep Creek Range) during 1991 and 1992, but that gains through the Sheep Creek Range were not appreciable. They also suggest that baseflows were not present in Rock Creek at the gage just downstream of the Sheep Creek Range (Maurer et al. 1996). In 1998, Rock Creek actually lost baseflow through the Sheep Creek Range, but still flowed in the low-flow season downstream of the range. Based on 1998 data (Barrick 1999a), overall baseflow averages for Rock Creek indicate significantly greater baseflows than earlier monitoring data, probably as a result of higher precipitation in more recent years.

Based on USGS data, Rock Creek as it flowed out of the Sheep Creek Range into Boulder Valley exhibited continuous flow through the lowest flow months of August and September in the drought years 1985 through 1989. However, with the exception of 1993, the stream did not flow during a large part of July, August, or September from 1990 through 1995. The long-term record at the USGS gage (1918 through 1998) indicates average flows of 1.25 and 1.40 cfs for August and September respectively, suggesting small perennial flows at that location during that time of year. Except for this short reach downstream of the Sheep Creek Range, Rock Creek frequently goes dry within Boulder Valley for a large part of the year.

Available data and interpretations for Susie Creek, Maggie Creek, and Marys Creek represent gaging conducted by the USGS and Newmont. These data have been collected during a relatively short period beginning in the early 1990s through the present. The middle portion of Susie Creek gains flow, possibly from small tributary contributions or from ground water inflows. Farther downstream in its lower reach, the channel loses flows by seepage into the underlying aquifer. Periods of no flow occur during the summer and fall (Maurer et al. 1996; Newmont 1999d).

Maggie Creek is the principal creek located just east of the Newmont South Operations Area in Maggie Creek Basin. Maggie Creek flows 41 miles southward to its confluence with the Humboldt River near Carlin. James, Soap, Simon, Cottonwood, Jack, Little Jack, Coyote, Spring, Haskell, Beaver, and Taylor creeks are tributaries of Maggie Creek. The Maggie Creek drainage area is approximately 400 square miles. Immediately north of the South Operations Area, Maggie Creek is confined by Maggie Creek Canyon, or the "narrows." This bedrock feature divides the Maggie Creek Basin into upper and lower basins. Maggie Creek generally flows as a perennial stream above the canyon and as an intermittent stream through most of the lower basin.

Flow gaging on Maggie Creek by the USGS was continuous from 1913 until 1924 at a station located above its confluence with the Humboldt River. Currently, the USGS operates three gaging stations on Maggie Creek, installed in 1989, 1992, and 1996. During the 1913 to 1924 period of record, average daily discharge of lower Maggie Creek was 23.2 cfs. In general, average monthly flow in Maggie Creek at the mouth is less than 10 cfs during 7 months of the year, and approximately 100 cfs during the months of April and May. High flows in Maggie Creek occurred in March 1993 and March 1996 with more than 100 cfs measured at all stations. In summer and fall, lower Maggie Creek commonly dries up while upper Maggie Creek maintains flow rates of 0.2 to 0.5 cfs.

Maggie Creek has both gaining and losing reaches along its length. The USGS has measured flow at several locations along Maggie Creek on the same day to evaluate water gain or loss. Flow measurements during the period 1988 to 1992 suggest that Maggie Creek gains in flow above Maggie Creek Canyon and loses water through and below the canyon (USGS 1992). In its upper reach the stream loses flows, with losses ranging from approximately 0.5 to 1.2 cfs. The middle reach of Maggie Creek (to Maggie Creek Canyon) is an inconsistently gaining or losing reach depending on specific location, year, or season. Farther downstream, flows are lost along the length of Maggie Creek Canyon. Lower Maggie Creek, from the canyon to the mouth, is a generally losing reach except during occasional snowmelt contributions from the intervening watershed area (Maurer et al. 1996; Newmont 1999d).

Susie Creek flows 29 miles south to the Humboldt River and has a drainage area of approximately 212 square miles. A USGS surface water station was installed near the mouth of Susie Creek in April 1992. In addition, Newmont has established five streamflow measurement sites along Susie Creek. In most years, Susie Creek is intermittent. The lower reaches are typically dry in the months of July to October. Susie Creek flow was measured by the USGS at a point 16 miles above its confluence with the Humboldt River during the period 1956 to 1958. Average annual flow at this location was approximately 6 cfs with average monthly flows ranging from 0.11 to 29.3 cfs (USGS 1963). Maximum annual flows for the 3 years of measurement were 184, 161, and 89 cfs (USGS 1963). Flow data on file with BLM show a high flow of 60 cfs recorded for April 30, 1985, at a location approximately 4 miles above Susie Creek's mouth. At the USGS surface water station on Susie Creek near its mouth, average annual flow is about 8 cfs for the period 1992 to 1996. In 1996, April flows peaked at approximately 276 cfs, and Susie Creek was dry from July through October (USGS 1999b). The middle portion of Susie Creek gains flow, possibly from small tributary contributions or from ground water inflows. Farther downstream in its lower reach, the channel loses flows by seepage into the lower aquifer.

Marys Creek flows approximately 13 miles southeast before entering the Humboldt River west of Carlin. The Marys Creek drainage area is approximately 75 square miles. A continuous-recording USGS stream gage has been operating on Marys Creek below the Carlin Springs since November 1989 (Lower Marys). In addition, Newmont maintains one streamflow measurement site along Marys Creek. Depending on the location, Marys Creek may be an ephemeral or intermittent stream, with the exception of the lowermost reach, which is sustained by spring flow from Carlin Springs. Flow characterization by the USGS based on gaging during the last part of the 1985 to 1993 drought indicates an ephemeral regime. Data collected in the uppermost reaches by Newmont from 1993 through 1998, however, indicate small flows occur year-round in the headwater (Newmont 1999d). Although 1993 was a wet year (based on river flow at Carlin), 1994 was drier than normal. These flows are probably lost to channel seepage as the stream traverses valley alluvium downstream.

High flows typically are recorded in March and April and low flows in October and November. Flow at the surface water station typically shows a sharp decline in April or May corresponding to the start of irrigation on the Maggie Creek Ranch upgradient from the Carlin Springs (Newmont 1999d). The town of Carlin also obtains some municipal water from the springs, which affects flow measurements downstream at the surface water station. The gage shows maximum and minimum discharges of 400 and 0.6 cfs, respectively (USGS 1999b).

Surface Water Rights

An inventory of surface water rights and applications for surface water rights provided information on locations and status within the hydrologic study area. According to the Nevada Division of Water Resources records, a total of 121 water rights and an additional 6 applications under *ready for action* status are listed in the state database. Of the 121 water rights, 46 have *certificated* status, 38 are *vested* water rights, 24 have *permit* status, 9 are listed as *proofs* (or decreed water rights), and 4 are under *reserved* water rights status. Information on these rights and applications for rights is summarized in Appendix A, Table A-2; the point of diversion locations are shown in Figure 3-8 (Nevada State Engineer's Office 1999, 2000). Note that the inventory excluded all rights and applications for rights owned by Barrick or Newmont for mining and milling use. The primary uses for the water are stock watering, municipal, irrigation, and domestic.

3.1.3 Humboldt River Study Area

For purposes of examining potential impacts to the Humboldt River from mine dewatering discharges, the Humboldt River study area was defined as extending from the USGS stream gage near Carlin, Nevada (10321000) to the Humboldt Sink downstream. The river study area is shown in Figure 1-1 (Basin Boundaries and Humboldt River Features).

In addition to the mining companies, major sources of flow and water quality data for the region included the USGS; the Nevada Department of Conservation and Natural Resources (NDCNR) - Division of Water Resources, Division of Water Planning, and Division of Environmental Protection; the Natural Resources Conservation Service (NRCS); Pershing County Water Conservation District; NDOW; and the USFWS.

3.1.3.1 Humboldt River Water Uses

Throughout its length, the Humboldt River has historically supported diverse water demands and beneficial uses. In addition to recreational uses and providing aquatic and wildlife habitats, the river supplies water for commerce and domestic uses. Primary water development sectors within the basin have been agricultural (irrigated crops and livestock), mining, and municipal uses. Data and projections regarding dominant uses of the river are shown by county in Tables C-1 and C-2 in Appendix C. Graphical summaries of demands and consumption in the Humboldt River basin are depicted in Figures C-1 and C-2 in Appendix C. These data show that the irrigation and livestock sector is by far the largest use of water in the basin. The proportion of mining and municipal uses is projected to vary over time.

Actual water use data for 1995 for the five-county area that comprises the Humboldt River Basin is summarized in Table C-3 in Appendix C. These data show that 87.5 percent of water withdrawal was for irrigation/livestock use. Mining was the next largest water user at 10.7 percent, followed by municipal/industrial (1.7 percent) and domestic (0.1 percent). Elko and Humboldt counties had the majority of irrigation and livestock water use, whereas Eureka and Humboldt counties had most mining-related water withdrawal. Total water withdrawn in the Humboldt River Basin in 1995 was relatively evenly divided between ground water and surface water sources. In addition, approximately 50 percent of all water withdrawn in 1995 was consumed (Table C-4 in Appendix C). A considerable amount of the consumed water is due to evaporation from the ditches and reservoirs, as well as evapotranspiration by the plants that are irrigated.

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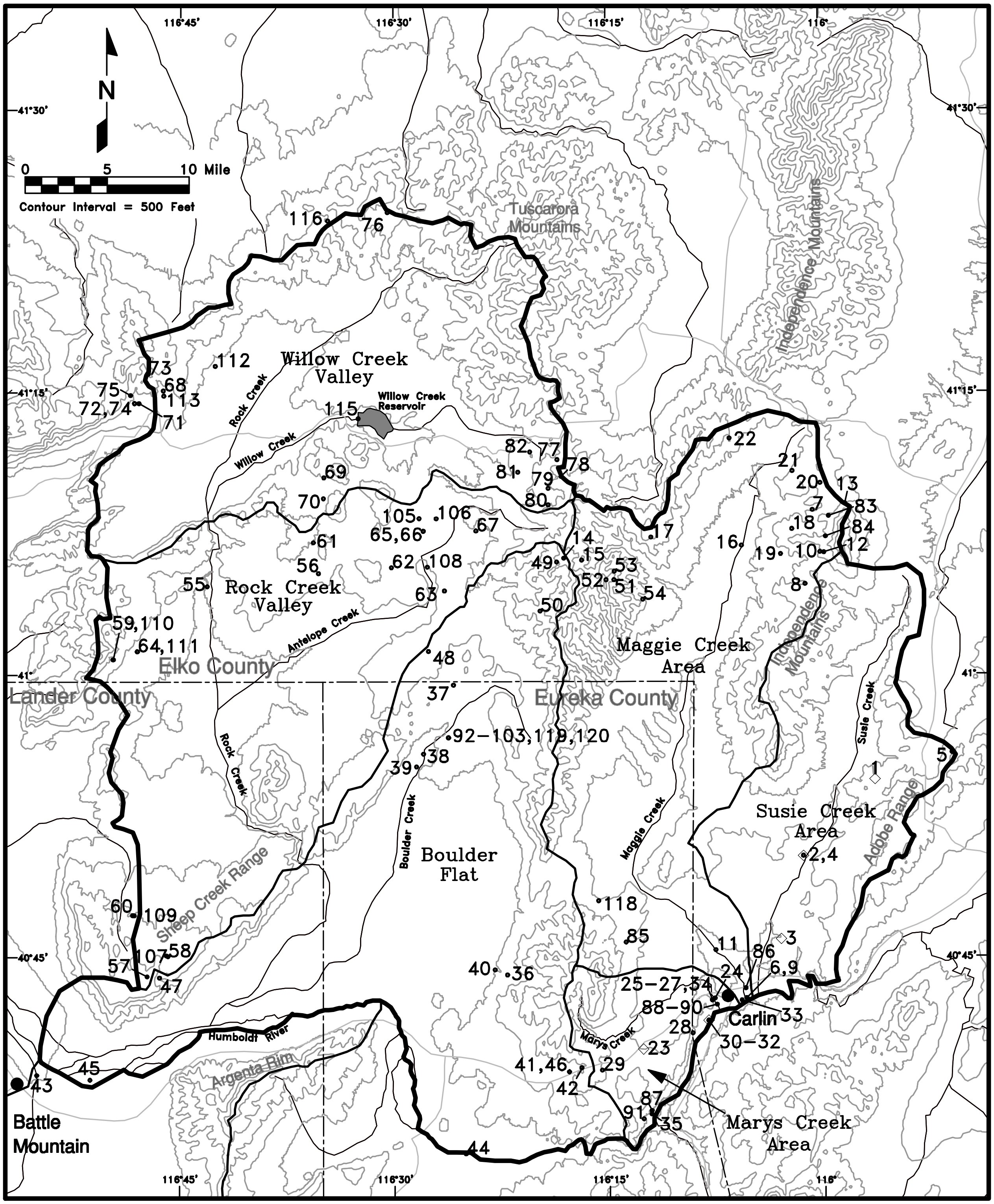

Legend

- Study Area
- Ground Water Basin Boundary
- Stream
- County
- 46 • Point of Diversion for Surface Water with Current Permit, Certificate, or Vested Status
- 23 ◇ Listed Point of Diversion for Applications for Surface Water Right (Application, Ready for Action, and Ready for Action Protested)

See Table A-2 for details

Figure 3-8

Surface Water Rights, and Application for Surface Water Rights in the Hydrologic Study Area

Tables C-3 and C-4 in Appendix C indicate that total water withdrawal in 1995 for the five specific counties in the Humboldt River Basin was approximately 2.2 million acre-feet, half of which came from ground water sources and the other half came from surface water sources. Table C-4 shows that the average consumptive use in 1995 for the same five-county area was about 49 percent of the total water withdrawal. Total consumptive water use for both surface and ground water in 1995 for the five-county area was about 1.1 million acre-feet. It generally can be estimated that consumptive use of surface water was on the order of 540,000 acre-feet for the year, which is less than the decreed and permitted water usage of approximately 667,000 acre-feet per year for the Humboldt River.

It should be noted that the water demands and consumption in the counties listed are not all made directly on Humboldt River surface flows; a substantial amount of demand is met by ground water sources or surface water sources tributary to the river. However, the data generally indicate the relative magnitudes of past and projected water uses in the basin. An additional use of Humboldt River water is at wildlife management areas at the Humboldt and Carson sinks and in habitats along the river.

Agricultural Irrigation Uses

As shown in Appendix C, agricultural uses dominate the demands on Humboldt River flows. Table 3-4 illustrates an approximate seasonal distribution of the annual irrigation demand that was used to evaluate potential changes in the surface water environment of the Humboldt River from Palisade to the Comus gage. Additional published estimates were used for assessments downstream of Comus (Eakin 1962; Eakin and Lamke 1966). The general monthly irrigation demands shown in Table 3-4 were approximated from seasonal requirements to meet priorities, as described by the NDCNR (1964).

Table 3-4
Seasonal Irrigation Demands
(acre-feet)

Reach	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Palisade to Battle Mountain	0	0	8,600	17,000	11,000	8,100	5,700	5,700	3,500	0	0	0
Battle Mountain to Comus	0	0	5,200	10,000	6,300	4,300	2,400	2,400	1,200	0	0	0

Note: The numbers have been rounded to two significant figures.

Irrigation Efficiency, Return Flow Pattern, and Return Location. Irrigation return flow is the portion of diverted water that is not consumed by evapotranspiration and that later returns to the stream system. The amount of water returned and the timing of its return vary in complex ways according to agricultural water management systems, the type of crop grown, and the nature of lands under irrigation. The general rate at which used irrigation water returns to the system can be expressed regionally as a percentage of the original diversions over time. Regional returns often lag the original diversions by some period of time and may extend over several months. Estimates of the fraction of irrigation water return flow range from 20 percent (NDWR 1997) to 40 percent (NDCNR 1964) of the water diverted.

The return flow pattern is the fraction of irrigation water (both surface runoff and ground water) returning to the stream system in the months following its application to irrigated land. The return flow pattern used to evaluate the changes in the surface water environment of the Humboldt River was developed from a Glover analysis (Glover 1978). The Glover parameters assumed in determining the return flow pattern are believed to be applicable to the irrigated areas along the Humboldt River (hydraulic conductivity = 10 feet/day, voids ratio = 0.20, and distance to stream = 1,000 to 5,000 feet). Based on the Glover analysis, the fraction of irrigation water returning to the stream system was assumed to return over a 5-month period. As a percentage of the total return flow, it is assumed that approximately 75 percent of the return flow would occur in the first month after diversion, 17 percent in the second month, 5 percent in the third month, 2 percent in the fourth month, and 1 percent in the fifth month.

This pattern represents a reasonable estimate of the monthly return flow fraction. Note that the return flow pattern does have an effect on the annual water balance as diversions occurring in September will not completely return until January of the following year. Historically, the last month of diversion is September; therefore, the majority of the water from the September diversion returns to the stream system by the end of October.

The Humboldt Project and Pitt-Taylor Reservoirs. Water from the Humboldt Project (see also Section 3.1.3.3) is used to irrigate approximately 40,000 acres, mostly in hay, in the Lovelock Valley. Operation and maintenance of the Rye Patch Dam, Reservoir, and associated outlets and conveyances are conducted by the Pershing County Water Conservation District. Return flows from irrigation are directed to the Humboldt Sink area (Toulon Lake or Humboldt Lake) immediately downstream of the Lovelock Valley via agricultural drains.

Rye Patch Reservoir and the Pitt-Taylor reservoirs are the largest surface water impoundments on the Humboldt River (Figure 3-9). They are located between Winnemucca and Lovelock approximately 100 miles downstream of the Carlin Trend mines. Rye Patch Dam is located on the river, and was completed in the mid-1930s. Rye Patch Reservoir can control approximately 194,300 acre-feet of water storage (USGS 1998a). It is an elongated narrow reservoir, somewhat wider and shallower at the upstream end. When full, its surface area is approximately 11,200 acres (17.5 square miles).

The Pitt-Taylor reservoirs (lower and upper) provide relatively shallow off-channel storage of water diverted from the river via the Pitt-Taylor Canal. These features are owned by the Pershing County Water Conservation District, and are not part of the federal Humboldt Project. A long dam on higher ground separates these reservoirs from Rye Patch Reservoir. Depending on storage, the total surface area of the Pitt-Taylor reservoirs may be up to approximately 4,600 acres (7.2 square miles). Evaporative losses from Rye Patch Reservoir and the Pitt-Taylor Reservoirs are estimated at 20,000 acre-feet/year (Eakin 1962).

Municipal and Other Water Uses

Water use estimates for the 1990-2020 period by other demand sectors in the five-county area of the Humboldt River Basin are presented in Tables C-2 and C-5 in Appendix C. Total water use projected for municipal water suppliers in this period ranges from approximately 12,000 to 26,000 acre-feet per year.

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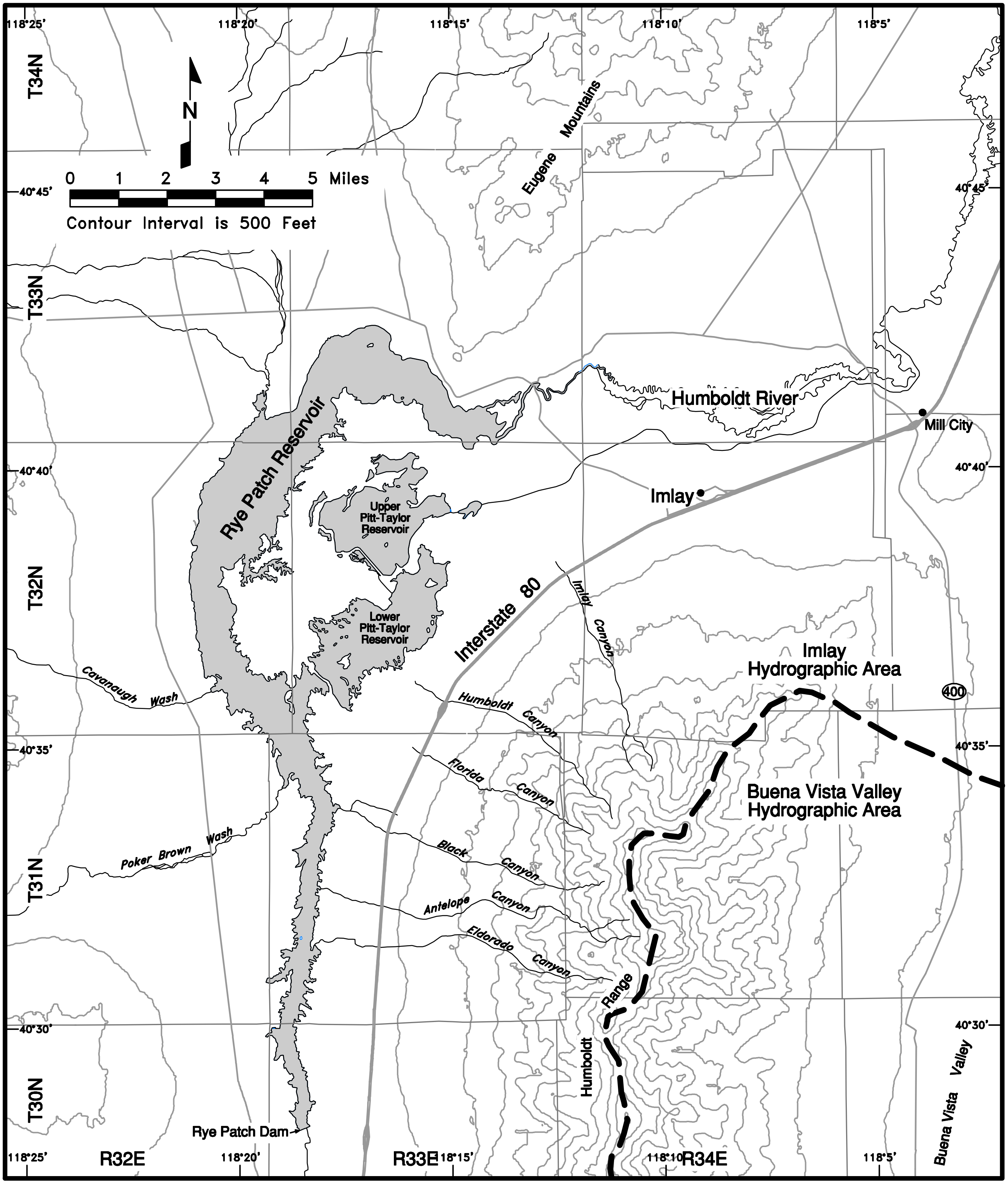


Legend

- Roads
- Interstate 80
- River or Stream
- Hydrographic Sub-Area Boundary

Figure 3-9

Rye Patch and Pitt-Taylor Reservoirs

Most municipal water use in the basin is by the City of Elko (6,000 to 15,000 acre-feet/year for the period 1990-2020).

Currently available water supplies for the communities included in Table C-5 are expected to be adequate beyond the year 2020 (Nevada Division of Water Planning 1992a). Another water user in the Humboldt River Basin is the Valmy Power Station, which consumes approximately 5,000 acre-feet/year, some of which is supplied by wells and by excess water from the Lone Tree Mine dewatering system.

Active NPDES permits for Elko, Eureka, Humboldt, Lander, and Pershing counties are presented in Table C-6 in Appendix C. A total of six discharges are permitted, four of which go to the Humboldt River. All of the Humboldt River discharges are from mining operations (Goldstrike, Lone Tree, and Gold Quarry). Total permitted discharge from these mines is approximately 300 cfs or 217,000 acre-feet/year (Table C-6). The remaining two permitted discharges are from the town of Lovelock (which discharges waste water to Toulon Lake) and the Nevada Division of Wildlife’s Gallagher Fish Hatchery in Elko County (which discharges waste water to Ruby Marsh).

Table C-7 in Appendix C shows the release of water from public sewage treatment facilities in 1990 for the five-county Humboldt River Basin area. These discharges totaled approximately 6,200 acre-feet/year and generally are disposed of via infiltration basins. Some of this water, therefore, likely recharges the Humboldt River.

3.1.3.2 Flow Regime

Humboldt River flow within the hydrologic study area has been measured over several decades by the USGS at gaging stations near Carlin, Palisade, Argenta, Valmy, Battle Mountain, Comus, Winnemucca, Rose Creek, Imlay, Rye Patch, and below Lovelock. Daily flows are presented in the USGS records for these gaging stations. The locations of key gaging stations and mine discharge outfalls are shown in Figure 1-1. The upstream gage at Carlin is located approximately 5.5 miles upstream of the Maggie Creek confluence. Barrick’s dewatering outfall on the Humboldt River is located between the Palisade gage and the former Argenta gage. The gage at Comus is located approximately 9 miles east of Golconda and 50 miles downstream of Barrick’s outfall. Discharges from Newmont's Lone Tree Mine enter the main branch of the river approximately 1 mile upstream of the Comus gage. The Imlay gage is immediately upstream of Rye Patch Reservoir, and the Rye Patch gage is immediately downstream of the reservoir. Therefore, the flows at the Rye Patch gage strongly reflect reservoir operations. During the 1950s, the Lovelock gage was located approximately 10 miles downstream of Lovelock and 8 miles upstream of Humboldt Lake. Flow measurements at that location were highly affected by reservoir operations and irrigation diversions and returns. Gaging below Lovelock was discontinued in 1959 and re-established by the USGS in 1998.

Cultivated lands and water management structures lie along the Humboldt River main stem and its tributaries, except where narrow canyons, deep channel networks, or unsuitable soils prohibit cropland uses. The dominant crop grown is native meadow hay, and the total amount of irrigable land has not changed significantly over the past 40 years (NRCS 1997). The drainage area and the area potentially under irrigation from river diversions are shown cumulatively for each gage in Table 3-5. The actual area irrigated varies greatly from year to year, depending on the availability of water from the river.

Table 3-5
Areas Upstream of Humboldt River Gages (square miles)

Gage	Cumulative Drainage Area	Cumulative Irrigated Area[1]	Incremental Irrigated Area[1]
Carlin	4,310	223	
Palisade	5,010	231	8
Argenta	7,490	unknown	unknown
Battle Mountain	8,870	303	72
Comus	12,100	>322[2]	>19
Imlay	15,700	>345	23
Lovelock	16,600	>448	105

[1]Incremental irrigated area is the area under irrigation from one stream gage to the next. For example, there are 8 square miles of irrigated lands between Carlin and Palisade. The cumulative irrigated area is the total amount of irrigated land upstream of the gage.
[2]Additional irrigated lands beyond those recorded under the Humboldt River Decree occur in this subarea.
Source: U.S. Geological Survey 1998a.

In addition to agriculture, mining operations in the area use a large volume of water. Nearly all of the water used for mining is ground water that is pumped from the mine areas. Several mining operations in the hydrologic study area pump more ground water for mine dewatering than they can use for mine processes and dust control (see Section 3.3.1.1). Primarily as a result of mining activity in the region, Humboldt River flow data have been recently analyzed by several investigators (HCI 1997a; JBR 1997; Maurer et al. 1996; RTi 1998; Simons & Associates, Inc. 1995a, 1997; and Zimmerman 1992b).

USGS daily stream gage records were used to assess the streamflow conditions on the Humboldt River for the periods January 1946 through May 1990 and June 1990 through December 1996 (RTi 1998). The period from January 1946 through May 1990 was chosen to establish the baseline (prior to dewatering) conditions. Streamflow data were requested from the USGS in Carson City, Nevada, for each of the following stations: Carlin, Palisade, Battle Mountain, Comus, and Imlay. The data received from the USGS are considered provisional for the period October 1994 through December 1996 but remained in the analysis as the best data available. Provisional data have been finalized and additional data have become available since the time of the original streamflow data analysis (RTi 1998). These data show substantially higher streamflow averages for recent years (1991 through 1998) than are depicted in the following tables due, in part, to precipitation increases since 1995. However, the essential points of the tables are still pertinent to the discussion: that a drought occurred in the late 1980s and early 1990s, and more importantly, that streamflow data for short periods can vary significantly from long-term averages.

The stations at Carlin, Palisade, Comus, Imlay, and Rye Patch have continuous data for the entire study period, including January 1946 through December 1996. The stations at Battle Mountain and Argenta have discontinuous records for the period of interest. Missing data at Battle Mountain and Argenta were synthesized for the periods of interest by means of statistical correlation with the gage data from Carlin, which showed the best fit with existing data. This approach yielded regression coefficients of 0.90 or above for most months. Quantitative analyses extended to the Comus gage, which is the closest gage downsteam of the Lone Tree Mine. All flows and related impacts from the mine discharges included in this investigation can thus be represented quantitatively in the river at the Comus gage. Significant irrigation withdrawals as well as channel losses and gains occur in the reach from Comus to Imlay, and from Rye Patch Reservoir to the Humboldt Sink. These lower reaches were examined qualitatively. The gage at Rye Patch was not used for river flow analysis because it is downstream of Rye Patch Reservoir and is highly influenced by reservoir storage and operation. The gage data for Valmy, Winnemucca, Rose Creek, and Lovelock were not incorporated into the quantitative flow analysis due to their relatively short periods of record and because they were discontinued several decades prior to this assessment. Average annual flow hydrographs for the selected stations are shown in Figure 3-10 (RTi 1998).

Except for its lower reaches near Lovelock, the Humboldt River is generally perennial throughout its length within the study area. Flows are highly variable and nearly cease during some low-flow periods. High flows in the river typically occur during the months of April, May, and June as a result of snowmelt; low flows usually occur in August, September, and October. Low flow is defined herein as streamflow during the period when minimal effects from man-made diversions and return flows, storm and snowmelt runoff, and evapotranspiration occur. Low flows for this study have been assessed as flow conditions during September, when the discharge records show minimal evidence of irrigation returns and autumn precipitation (RTi 1998).

The average flow on a yearly basis for January 1946 through May 1990 and June 1990 through December 1996 is summarized for the selected Humboldt River gages in Table 3-6.

Table 3-6
Average Annual Humboldt River Flows (cfs)

January 1946 - May 1990		June 1990 - December 1996	
Gage	**Flow**	**Flow**	**Percent of 1946-1990 Flow**
Carlin	383	269	70
Palisade	434	345	79
Argenta	391	262	67
Battle Mountain	395	279	71
Comus	365	232	64
Imlay	305	174	57

USGS records (and annual hydrographs developed from them) indicate that the highest flows on the river typically occur during June. Average high flows for the peak runoff month (June) for the periods from January 1946 through May 1990, and for June 1990 through December 1996, are summarized in Table 3-7.

Table 3-7
Average Peak Humboldt River Flows - June (cfs)

Gage	January 1946 - May 1990	June 1990 - December 1996	
	Flow	Flow	Percent of 1946-1990 Flow
Carlin	1,228	1,064	87
Palisade	1,270	1,046	82
Argenta	1,146	988	86
Battle Mountain	1,108	1,023	92
Comus	970	808	83
Imlay	732	555	76

Average low flows for the month of September are shown in Table 3-8 for the two periods of interest.

Table 3-8
Average Low Humboldt River Flows - September (cfs)

Gage	January 1946 - May 1990	June 1990 - December 1996	
	Flow	Flow	Percent of 1946-1990 Flow
Carlin	27	20	74
Palisade	41	37	90
Argenta	16	10	63
Battle Mountain	23	11	48
Comus	17	27	159
Imlay	48	23	48

It is important to note that the previous tables and discussions of flow conditions are based on averages representing a historical period of approximately 50 years. It is also important to note that wide variations in precipitation and snowfall occur in time and space throughout the region. As a result, wide variations in natural streamflows also occur, and these are masked by presenting data averages for the purposes of a general discussion. For example, from Table 3-7 the average peak flow (June flow) at Argenta from 1946 to mid-1990 is 1,146 cfs; the standard deviation for the same month over the same period is 1,037 cfs (RTi 1998). From Table 3-8, the average low flow (September flow) at Argenta is 16 cfs; the standard deviation is 27 cfs. At Palisade, the average peak flow is 1,270 cfs, and the standard deviation is 1,007 cfs (RTi 1998). Also at Palisade, the average low flow is 41 cfs, and the standard deviation is 37 cfs (RTi 1998).

As another illustration, over the long term, peak monthly flows on the river typically occur in June. That is, the highest flow over 1 month predominantly occurs in June. However, it also should be noted that high flows, sometimes as high or higher than June flows, occasionally occur in other months such as March, April, or May. For example, 1979 was an average flow year at Argenta. The average flow for the month of June that year was 1,006 cfs. For May, it was higher, 1,129 cfs. For March, the average flow was 995 cfs, 1 percent less than June. Peak daily flow for June of that year was 2,050 cfs on June 1. The same daily flow occurred on May 31. In addition, 1,660 cfs occurred on March 12; 1,760 cfs occurred on February 16; and the highest daily flow all year was 2,350 cfs on January 14. Four days earlier the river carried 87 cfs.

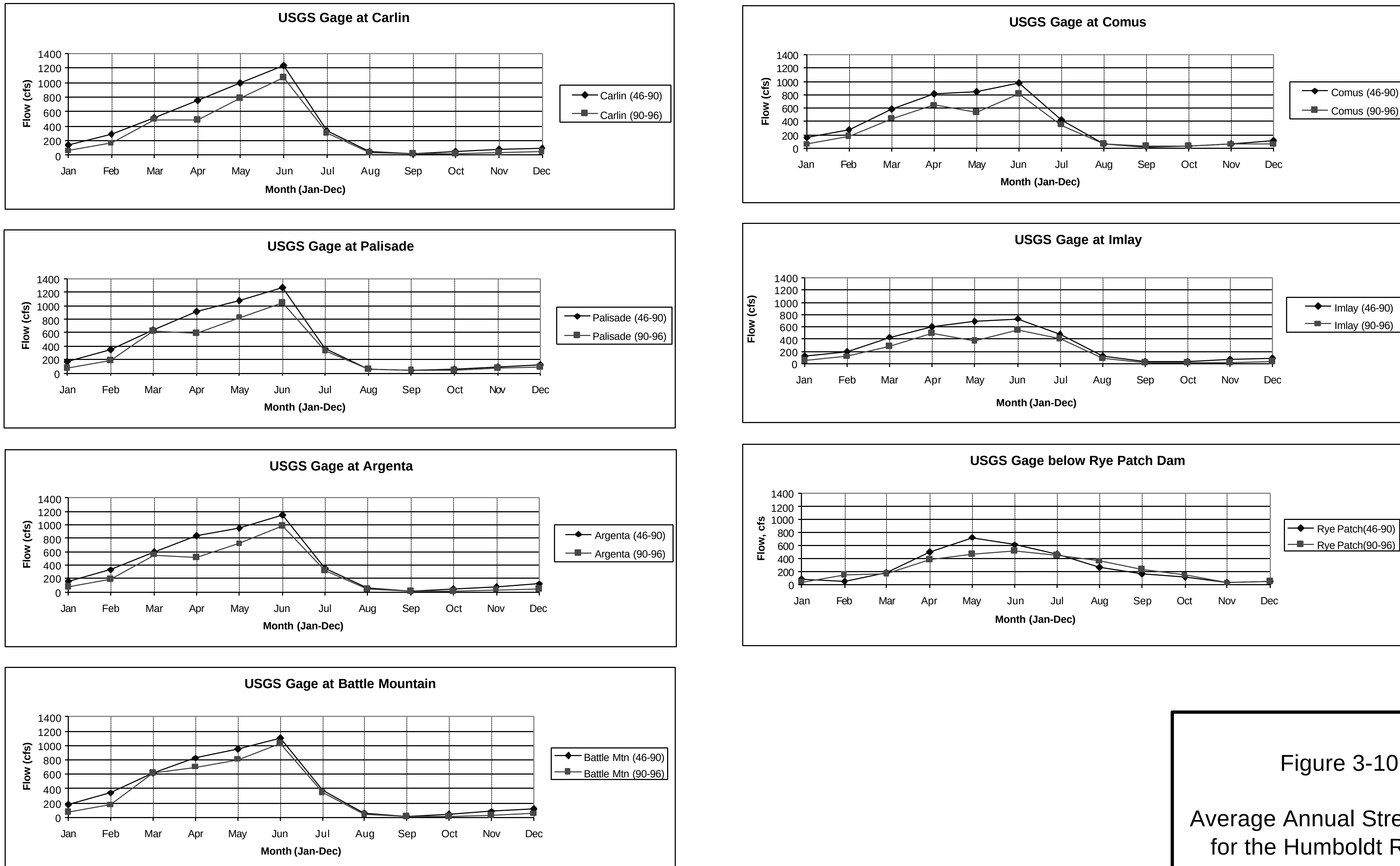


Figure 3-10

Average Annual Streamflows for the Humboldt River at USGS Gage Stations

Average monthly flows on the river are exceeded between 20 and 40 percent of the time. In June at Argenta, for example, the average monthly flow is 1,146 cfs for the period 1946 through mid-1990. June flows were higher than that in approximately 39 percent of those years. The average June flow in those exceeding years was approximately 2,000 cfs. September flows average 16 cfs at Argenta during the same period; this was exceeded in 22 percent of the years. The average September flow in those exceeding years was approximately 54 cfs. Similarly, substantially lower than average flows also occur much of the time. Clearly, wide variations in flow occur on the river through time. The average values presented herein are included as a means of generally depicting the flow conditions on the river, and to aid in a conceptual understanding of conditions as the river traverses the study area. Additional information about flow variations at various Humboldt River gages is shown in Appendix C, Table C-8.

Table 3-9 presents the estimated average annual gains and losses for the periods of interest at each of the selected Humboldt River gages. Long-term gains and losses are determined by comparing the average annual flows between successive stream gages.

Table 3-9
Mean Annual Humboldt River Gains and Losses (cfs)

	January 1946 - May 1990	June 1990 - December 1996
River Reach	**Flows**	**Flows**
Carlin to Palisade	+51	+76
Palisade to Argenta	-43	-83
Argenta to Battle Mountain	+4	+17
Battle Mountain to Comus	-30	-47
Comus to Imlay	-60	-58

Source: RTi 1998.

As can be seen in Table 3-9, the river reach from Carlin to Palisade is a gaining reach on an annual basis. This is primarily due to additional runoff as well as ground water discharge into the channel from the Maggie Creek, Marys Creek, and Susie Creek drainages. In contrast, data indicate that on an annual basis the river has losing reaches historically from Palisade to Argenta and from Battle Mountain to Comus. Water loss along these reaches is due to agricultural withdrawals, evapotranspiration, and infiltration into the alluvial aquifer. Between Argenta and Battle Mountain, the river historically shows no significant net gain or loss on an annual basis. Maurer et al. (1996) had similar findings that the river gains flow from Carlin to Palisade and overall loses flow from Palisade to Battle Mountain.

Baseflow gains and losses have been estimated between selected Humboldt River gages by Zimmerman (1992b). Using October flows, the latter indicates that a gaining reach occurs between Carlin and Palisade, such that baseflows at Palisade are about 19 cfs greater than flows at Carlin. This is consistent with Maurer et al. (1996). Between Palisade and Argenta, the river loses approximately 22 cfs. From Argenta to Battle Mountain, a slight gain occurs. From Battle Mountain to Comus, the river loses baseflows of approximately 10 cfs.

Similar values are shown for the periods of record identified in Table 3-10. The two periods used reflect similar values upstream of Argenta. Downstream of Argenta, the differences in the data may be partially caused by the effects of statistical streamflow data synthesis used for impact analyses, but are more likely due to increasing irrigated area and other discharge factors, which vary from year to year in the basin.

Table 3-10
Mean October Gains and Losses in the Humboldt River (cfs)

River Reach	January 1946 – May 1990 Mean October Flows	June 1990 – December 1996 Mean October Flows
Carlin to Palisade	+18.4	+20.6
Palisade to Argenta	-29.7	-30.1
Argenta to Battle Mountain	+5.1	-1.2
Battle Mountain to Comus	-9.7	+12.3
Comus to Imlay	+14.4	-4.5

Source: RTi 1998.

Maurer et al. (1996) used gage data from October 1946 through September 1981 to conduct flow duration analyses for the Humboldt River at Carlin, Palisade, Argenta, and Battle Mountain. The Battle Mountain gage was used for similar calculations by Simons (Simons & Associates, Inc. 1995a). The results of these analyses indicate that a flow of approximately 1,000 cfs is equaled or exceeded only 10 percent of the time. Similarly, a flow of approximately 2,800 cfs is equaled or exceeded only 1 percent of the time. The median flow is approximately 120 cfs, indicating that flows are greater than this half of the time, and less than this half of the time. By examining the results in Maurer et al. (1996), it can reasonably be assumed that these results closely fit the Argenta data as well, except for the lowest flows (less than 1 or 2 cfs).

In Table 3-10, it can be seen that substantial flow losses are typical downstream of Battle Mountain. Downstream of the Comus gage, substantial losses in river flows also occurred in a majority of the years specifically investigated in USGS studies. Between the Comus gage and the Pershing County line, the average annual loss was 17,000 acre-feet for the period 1949-1962 (Cohen 1964). Spring and summer losses were higher than the annual average due to irrigation withdrawals, seepage to ground water, and evapotranspiration. Flow losses in the river for February though June averaged 28,000 acre-feet between Comus and the Pershing County line. Flows increased somewhat in the river from July through January as a result of irrigation returns and ground water contributions. Downstream of the Pershing County line to the Imlay gage, approximately 5,000 acre-feet per year were lost from the river during the period 1951-1962 (Eakin 1962). Flow losses or gains varied widely in individual years for both of the reaches described above, but it can be seen that on the order of 22,000 acre-feet/year were lost between the Comus gage and the upstream end of Rye Patch Reservoir. With an additional 20,000 acre-feet/year estimated to evaporate from the reservoir itself, it can be seen that on average a substantial amount of river flow was lost from the surface water system between Comus and the USGS gage near Rye Patch. This general concept is supported by more extensive gaging data depicted in Table 3-9.

Sediment Discharges

Humboldt River sediment discharge data from the USGS were examined for the gage locations in the study area that have reasonable periods of record. These gages include the Humboldt River near Carlin, near Imlay, and near Rye Patch (Figure 1-1). Essentially no sediment discharge data exist in the Palisade to

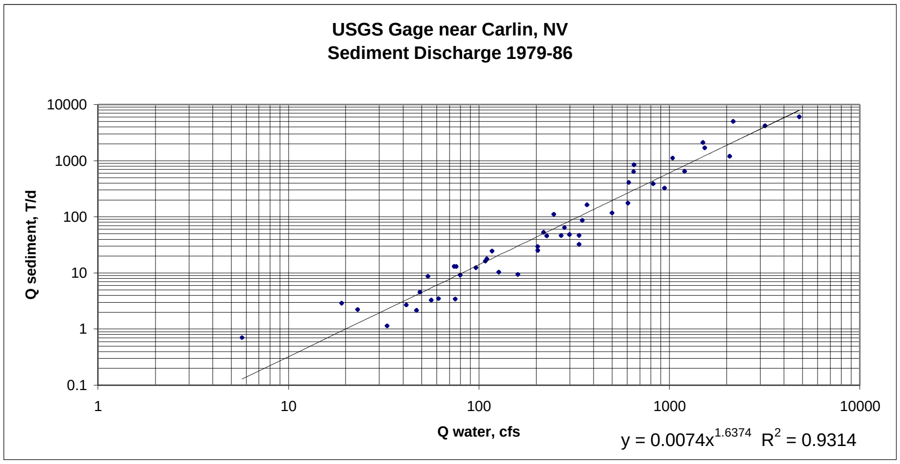
Comus area. Sediment discharge data for the period of record common to the gages were plotted and a line of best fit was determined to relate sediment discharge to flow rate in the river (Figure 3-11).

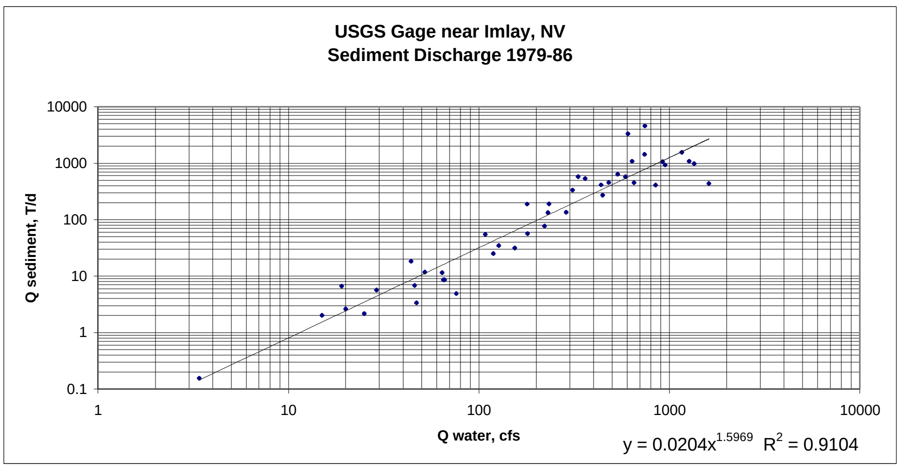
There is considerable variation in the data, even at a single station for a given river flow. However, general relationships can be seen at a single station and between stations. Between Carlin and Imlay, a general increase in sediment discharge for a given water flow can be identified from the graphs. For example, the general sediment discharge for a flow of 100 cfs is approximately 14 tons/day at Carlin and 32 tons/day at Imlay. For 1,000 cfs in the river, the general sediment discharge rates are approximately 605 tons/day and 1,260 tons/day at Carlin and Imlay, respectively. This is likely due to the increased sediment supply from the additional drainage area and channel length at Imlay versus Carlin. Substantially less sediment discharge occurs for a given flow at the Rye Patch gage in comparison to either Carlin or Imlay. This is due to the sediment trapping effects of Rye Patch Reservoir, which is between the Imlay and Rye Patch gages. The estimated sediment discharges at the Rye Patch gage are approximately 9 tons/day for a flow of 100 cfs and 94 tons/day for a flow of 1,000 cfs.

With regard to data variations, it can be seen that for flows of approximately 55 cfs at Carlin, the sediment discharges range from approximately 3.5 to 8.5 tons/day. For flows on the order of 1,000 cfs, sediment discharges range from approximately 325 to 1,120 tons/day. Similar variation exists in the Imlay and Rye Patch data. It should be noted that sediment discharge data portray a synthesis of all the random and instantaneous sediment-related events in the watershed upstream of the monitoring point. Thus, one point in the Carlin data reflects cropland uses; grazing activity, and other land uses; the amount and timing of rainfall and snowmelt; re-entrainment of sediment that may have been stored along the channel for years; and other incidental disturbances along the river for the entire upstream watershed. Accounting for this multitude of factors historically is unrealistic. The same limitation exists at Imlay and Rye Patch. Therefore, although general statements can be made for data averaged over a period of time, the data do not allow specific causes and effects to be separated at specific times or flow events.

Regional River Channel Geometry

The configuration and habitat associations of the Humboldt River have been intensively examined over much of the study region by the Nevada Division of Wildlife (Rawlings and Neel 1989; Bradley and Neel 1990; Bradley 1992; Neel 1994). In particular, these studies included quantification of river length and sinuosity from the Dunphy area to near Rye Patch Reservoir. Sinuosity is the ratio of river length to valley length, and it is commonly used as a measure of river meandering. Higher sinuousity values indicate a higher degree of meandering. Changes in the river configuration over time are shown in Table 3-11 for general locations in the cumulative study area. The data used to develop Table 3-11 are nearly continuous over the length of the river indicated. Small gaps do exist in the data; however, it is reasonably representative of channel conditions along the section from Dunphy to Imlay. The measurements were made from USGS topographic quadrangles, historical aerial photographs, and additional aerial photos taken in 1985 when the investigation was initiated. The date of the historical information used in the analysis is shown in the second column; the 1985 data were used for comparison.





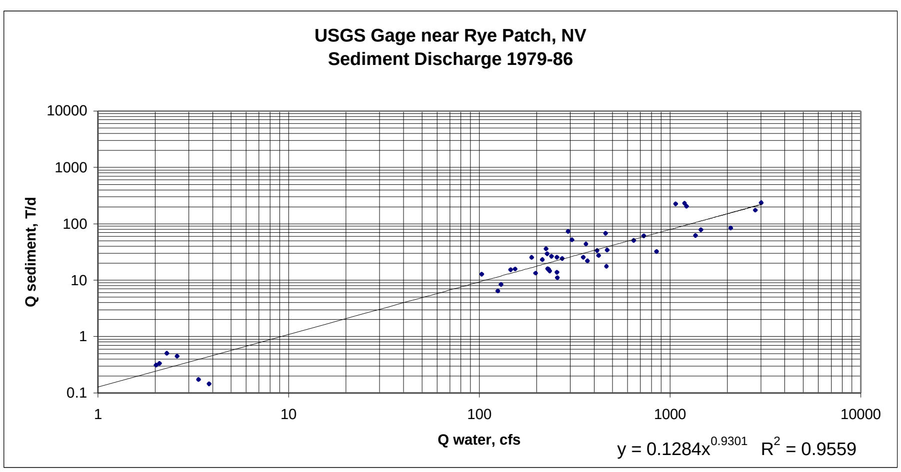


Figure 3-11

Humboldt River Sediment Discharges

Table 3-11
Historical Changes in Humboldt River Configuration

General Study Location	Historical River Length, miles (date)	1985 River Length, miles	Total Change, miles	Total Percent Change	Historical Channel Sinuosity	1985 Channel Sinuosity	Change
Dunphy	19.7 (1965)	15.1	-4.6	-23.4	1.62	1.25	-0.370
Argenta/Rock Creek	15.5 (1957)	13.7	-1.8	-11.6	1.26	1.11	-0.150
Battle Mountain Area	3.8 (1957)	3.7	-0.1	-2.6	1.69	1.64	-0.050
Valmy	20.1 (1954)	16.3	-3.8	-18.9	2.53	2.05	-0.480
Valmy	6.0 (1976)	5.2	-0.8	-13.3	2.06	1.79	-0.270
Valmy	3.4 (1965)	3.1	-0.3	-8.8	1.10	1.06	-0.040
Valmy	3.5 (1965-66)	3.5	0.0	0.0	1.17	1.17	0.000
Valmy	18.6 (1965)	17.8	-0.8	-4.3	1.58	1.57	-0.010
Comus	5.4 (1965)	5.3	-0.1	-1.9	1.28	1.26	-0.020
Comus	5.0 (1945, 1965)	5.3	0.3	6.0	1.85	1.96	0.110
Golconda	1.5 (1965, 1983)	1.6	0.1	6.7	1.50	1.60	0.100
Golconda	20.5 (1965)	20.1	-0.4	-2.0	1.71	1.68	-0.030
Winnemucca	7.6 (1983)	8.4	0.8	10.5	1.81	1.74	-0.070
Winnemucca	3.6 (1983)	3.5	-0.1	-2.8	1.16	1.13	-0.030
Winnemucca	4.7 (1983)	4.7	0.0	0.0	2.35	2.35	0.000
Winnemucca	3.5 (1982-83)	3.5	0.0	0.0	1.84	1.84	0.000
Winnemucca	5.3 (1982-83)	5.3	0.0	0.0	2.41	2.41	0.000
Winnemucca	5.8 (1976)	5.7	-0.1	-1.7	2.23	2.19	-0.040
Below Winnemucca	11.7 (1976)	10.3	-1.4	-12.0	2.21	1.94	-0.270
Imlay	17.4 (1976, 1982)	17.1	-0.3	-1.7	1.66	1.63	-0.030
TOTAL	**182.6**	**169.2**	**-13.4**	**-7.3**			

Source: Bradley and Neel 1990; Bradley 1992; Neel 1994.

The table indicates that a net loss of approximately 13.4 miles of river length has occurred over the two to three decades represented by the data. Substantial loss of river length and sinuosity has occurred in the Dunphy and Argenta areas and downstream of Winnemucca. In other locations, such as near Comus and at or slightly upstream of Winnemucca, the river has apparently both increased and decreased its length. Little or no change is shown over much of the river, particularly where the historical data represent conditions only 2 or 3 years prior to 1985. Differences of less than 0.1 mile in river length may be caused by small measurement errors on the maps and photos. From the date of the baseline data, it can be seen that channel changes have occurred to different degrees at different locations. Whether the changes occurred gradually over time or resulted from a few isolated events is not known. A mixture of both long-term and short-term factors probably contributed to the river conditions. However, it can be seen from the data that the river geometry has been in flux historically, prior to mining discharges. Some river locations have undergone significant adjustment, while others are relatively unchanged.

A number of factors must be considered when reviewing Humboldt River channel characteristics. First of all, the concept of stability may have different interpretations when applied to a dynamic natural river system.

The distinction is between the balance of flow and sediment transport processes within a system in motion versus the immobility of a river's position in relationship to civil boundaries or structures.

Variables such as channel gradient, length, width, depth and sinuosity refer to conditions that may be balanced (dynamic equilibrium) or not as a stream channel migrates or otherwise adjusts itself within an alluvial valley system. From a geomorphic viewpoint, a river can be thought of as being in balance if these relationships are maintained, even though the river may migrate widely across its floodplain. In short, changes in channel position do not necessarily imply instability within the river system. In contrast, efforts to stabilize or maintain the channel position at a given location often promote imbalances elsewhere, both upstream and downstream.

Within the past several decades, several major activities have taken place along the Humboldt River that have affected its position and geometry. These include several miles of federal channel straightening in the 1950s near Argenta and east of Comus. In addition, construction began on what is now the Interstate 80 system in the early 1960s. In combination with railroad structures and a narrow valley, the highway bridges at Dunphy have maintained the channel location there. The river position fluctuates upstream and downstream of this area. In recent decades, several irrigation structures have been built across the river. Over a longer time, railroad and municipal embankments have been built and maintained, and streamside vegetation has been altered as a result of various land use conversions (Rawlings and Neel 1989).

In 1984, extremely high flows occurred naturally in the Humboldt River. The highest recorded instantaneous peak flow at the Comus gage occurred on April 24 of that year and was 9,900 cfs. The highest recorded daily mean flow occurred the next day and was 9,640 cfs (USGS 1998a). On the basis of data gathered since 1946, these flows were roughly 10 times the peak flow for an average year at the Comus gage. The extreme flows cut across meanders, eroded banks, scoured the existing bars and terraces, and created new sediment deposits either as bars or thin veneers over the lower terraces.

In summary, it is probable that over several decades, alterations and infrastructure development all along the river have essentially anchored several locations into place and caused other reaches to continually adjust. Preliminary USGS information for the gage at Comus indicates that between 1988 and 1997, the river channel has widened and filled such that the general bottom elevation was between 0.5 feet and 1.5 feet higher in 1997 than in 1988 (USGS 1998a). In addition, aerial photographs indicate that several meanders have been cut off immediately upstream of the gage since the 1960s. Extensive lateral migration of the river channel also has occurred historically in the Dunphy area.

3.1.3.3 Regional Features and Conveyance Structures

In addition to water management systems associated with mining and municipal uses, numerous flow structures and conveyances occur within the study area. These are primarily used for agricultural purposes and form a complex system of diversions and returns on the Humboldt River and its tributaries. Notable diversion features from east to west along the main Humboldt River channel are listed for the study reach in Table 3-12. Additional ditches and controls interconnect river tributaries throughout the study area.

Table 3-12
Major Conveyance Structures Along the Humboldt River Study Reach

Structure	Approximate Location
Diversion flumes	1 mile southwest of Carlin
Diversion dam and ditch system	Harney, 8 miles east of Beowawe
Anderson-Highline Canal takeout	3 miles southeast of Beowawe
Corbett Canal takeout	2 miles southeast of Beowawe
Merchant Canal system takeout	Beowawe
Westside Ditch takeout	Beowawe
Rose Canal takeout	3.5 miles southeast of Dunphy
White House Dam	Dunphy
Bluehouse Ditch	3 miles east of Dunphy
Ditch	3 miles east of Battle Mountain
25 Ranch ditch system	7 miles northwest of Battle Mountain
Ditch	Ellison Ranch
The Dike	2 miles south of White House Ranch
Ditch	White House Ranch
Dam	Red House
Dam	2 miles west of Red House
Dam	1.5 miles southeast of Comus
Stahl Dam and French Canal diversion	2 miles east of Golconda
CS Dam	3 miles southeast of Button Point
Various dikes, headgates, and ditches	Button Point vicinity
Reinhart Dam	1.5 miles north of Winnemucca
Diversion dams and ditch system	2 miles northeast of Rose Creek
Pitt-Taylor Diversion Canal takeout	1.5 miles north of Mill City
Pitt-Taylor Dam and reservoirs	2.5 miles west of Humboldt
Rye Patch Dam and reservoir	1.5 miles northwest of Rye Patch
Young Dam, levees and diversion takeout	2 miles north of Colado
Pitt Dam	4.5 miles northeast of Lovelock
Irish-American Dam	3.5 miles northeast of Lovelock
Rogers Dam	1.5 miles northeast of Lovelock
Numerous gates, canals, ditches, and flumes	Lovelock area and downstream

Historically, an area of wetlands, abandoned channels, and associated wildlife habitats existed in the Argenta area in Lander County about half way between Battle Mountain and Dunphy near the former Argenta stream gage (see Figure 1-1). This area was informally known in the region as the Big Slough. Its size ranged between 1,500 acres and 5,000 acres, depending on the source of the information (Elko Daily Free Press 1997). It formed part of the Community Pasture bought by the U.S. Bureau of Reclamation in the 1930s in an effort to acquire water rights for Rye Patch Reservoir. The reservoir, pasture, and associated irrigation and water management infrastructure collectively form the Humboldt Project (see Section 3.1.3.1), which was approved by Congress in the 1930s. Water rights for the Community Pasture lands were transferred downstream to support the project, which is operated and paid for by the Pershing County Water Conservation District. Until the late 1950s, the marsh area supported extensive zones of willow and other riparian and wetland communities that, in turn, provided habitat for large numbers of waterfowl, as well as shorebirds, upland game birds, deer, and antelope (McColm 1994).

During the late 1950s, the area was drained by a Federal river channelization project, which straightened the course of the river for several miles through the Argenta vicinity and elsewhere along the river. The purpose of the channelization project was to conserve water in the river by reducing seepage and evapotranspiration, and ultimately to ensure that the water rights purchased by the U.S. Bureau of Reclamation actually resulted in additional water being supplied to Rye Patch Reservoir. The channelization was devised and undertaken by the U.S. Bureau of Reclamation, as a result of a directive from the Nevada Department of Conservation and Water Resources to demonstrate that the amount of water acquired was actually available at Rye Patch and downstream.

In recent years, this area has been referred to as the former Argenta Marsh. Having complied with the Humboldt Project reimbursement schedule for decades, the Pershing County Water Conservation District has recently applied to the federal government to receive title to the Humboldt Project properties. This process has generated public comment and involvement concerning the use and management of project lands. The concept of restoring water to the Argenta Marsh and improving habitats there has been supported by the NDOW and other public and private organizations, although the actual mechanisms for doing so require further definition and examination. Conceivably, mine discharge water could be diverted into the area through an old system of irrigation ditches. The feasibility of marsh restoration, water rights issues, and the long-term maintenance of marsh habitats after mine discharges cease are ongoing topics of discussion between the Pershing County Water Conservation District and other entities in the region.

The Humboldt River terminates at the Humboldt Sink approximately 15 miles southwest of Lovelock. The sink consists of two shallow lakes, Humboldt Lake and Toulon Lake, and a large area of alkali flats (Figure 3-12). The extent of the lakes varies widely from year to year, depending on the amount of water flowing into them from the river and agricultural drains. The total land area at the sink is on the order of 40 square miles.

The river is channelized for several miles upstream of the sink. Other major drains near the sink include the Toulon, Army, Lovelock Irrigation and the Graveyard drains, which primarily route agricultural return flows. Ultimately the drainages combine so that the Toulon Drain, Army Drain, and the Humboldt River form the major surface water conveyances into the Humboldt Sink. When water is available, the Humboldt Drain at the southwestern end of Humboldt Lake allows conveyance of water out of the Humboldt Sink to the nearby Carson Sink through an area of alkali flats and the Humboldt Slough. Recent USGS data indicate that flows between approximately 550 to 950 cfs passed through the Humboldt Drain toward the Carson Sink in the late summer of 1998 (USGS 1999b). The USGS gage near Carlin exhibited nearly average flows for that period as did the gages at Imlay and Rye Patch. It is not known if the flows through the Humboldt Drain in 1998 are representative of average conditions or how much of that flow actually reached the Carson Sink.

The USGS operated a streamflow gaging station on the Humboldt River downstream of Lovelock from 1950 to 1959, and has conducted new gaging and sampling at the location in 1998 and 1999 (USGS 1999b; Thodal 2000). Flows in the latter period include recent high-flow years as well as possible effects from mine dewatering. They are within the range of flows exhibited at the gage from 1950 through 1959. The 1950s

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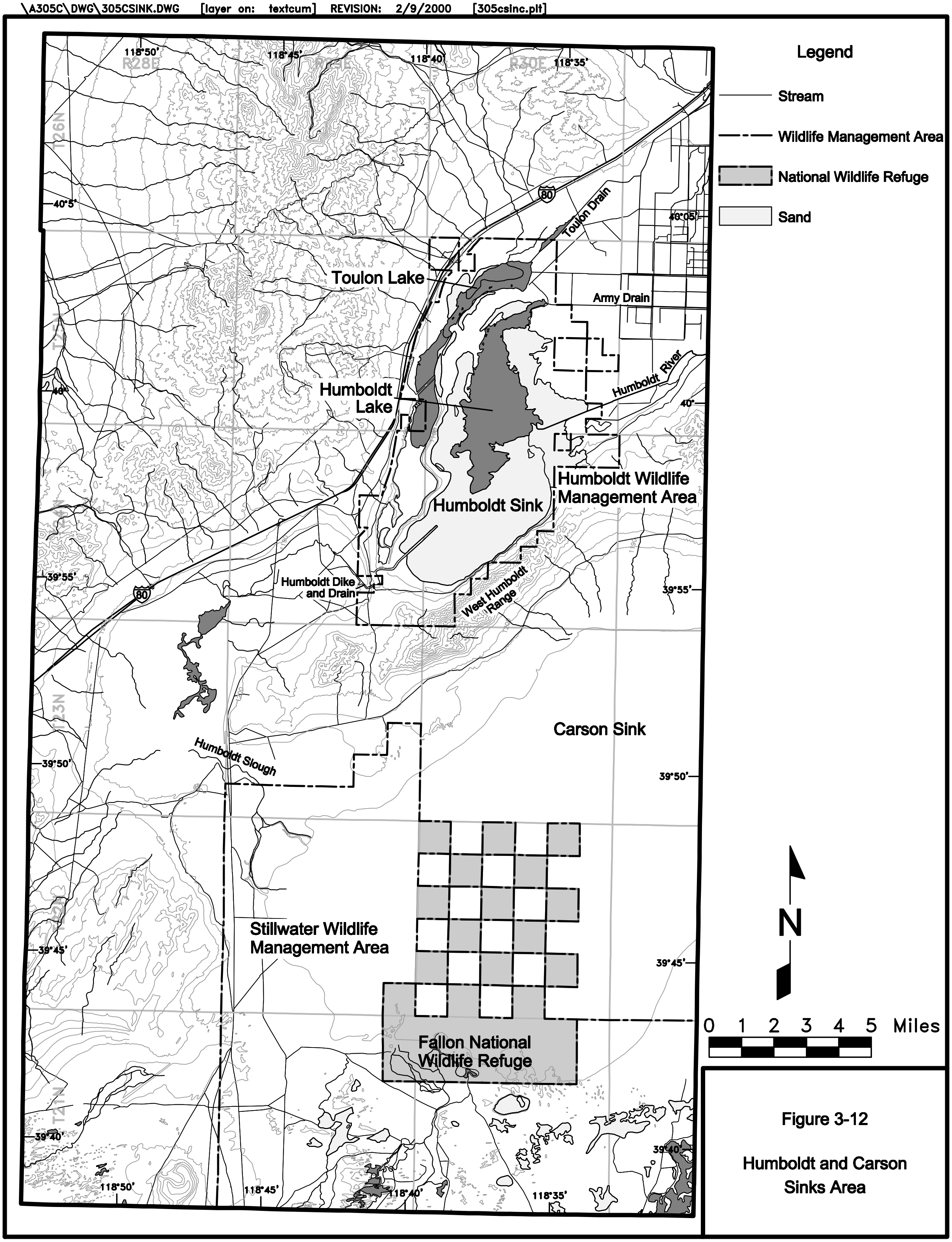

Figure 3-12

Humboldt and Carson Sinks Area

were composed of both high-flow years and low-flow years on the river, but are somewhat lower in overall average compared with the periods of record at other gages used in this assessment. Based on these limited flow measurement data, approximately 42,000 acre-feet/year flowed into the sink via the river below Lovelock. A very general assumption for the average annual diversion rate for the Lovelock Valley can be estimated by subtracting the river flows past Lovelock (available for 1950 through 1959) from the Rye Patch gage flows for the same period. This indicates that on the order of 105,000 acre-feet/year were diverted for use in the Lovelock Valley. Both high and low flows are represented in this period, although the Rye Patch average for the period is only about 75 percent of the 1946-90 average. Assuming a 30 percent return from the 105,000 acre-feet/year diversion, 31,500 acre-feet/year also flowed to the sink through seepage and drains as a general estimate. Coincidentally, with the 42,000 acre-feet/year flowing in the river, these figures sum to the approximate value (74,000 acre-feet/year) of surface and ground water outflow from the Humboldt Basin into the sink as indicated by Eakin and Lamke (1966). Normalizing these values to the 1946 through 1990 period of record used for other premining flow analyses, approximately 56,500 acre-feet/year flowed into the sink through the lower river, and 42,500 acre-feet/year of agricultural return flows entered the sink through drains and seepage, as broad estimates.

Mean annual rainfall in the sink area is approximately 5.4 inches (NOAA-CIRES 1999). With approximately 40 square miles of area, on the order of 11,500 acre-feet/year are contributed to the sink by direct precipitation. Combined with the inflows, on the order of 110,000 acre-feet/year are lost at the Humboldt Sink by evaporation, transpiration, and occasional overflow to the Carson Sink. Note that this is a general approximation based on limited data and simplifying assumptions; the actual contributions and losses at the sink vary widely from year to year.

3.1.3.4 Humboldt River Surface Water Rights

Many surface water rights exist within the Humboldt River study area, some dating from the early 1860s. Hundreds of rights are held for diversion of river water, and additional rights exist along the tributaries. A complete listing would be too large to include in this document. A concise listing of surface water rights and a discussion of related issues for the Humboldt River is presented in "*Humboldt River Water Distribution*" (Hennen 1964); although changes have occurred since its publication, this document indicates the nature of Humboldt River water rights. Humboldt River surface water rights above Palisade are administered under the Edwards Decree of 1935. The Bartlett Decree of 1931 applies to and is used in the distribution of river water below Palisade. Additional information is publicly available from the NDCNR, Division of Water Resources, in Carson City.

3.1.3.5 Humboldt River Water Quality

Available water quality information was compiled for all Humboldt River stations located between Carlin and the Humboldt Sink. Water quality data exist for most of the monitoring sites shown in Figure 1-1. Since mining related discharges to the river began in early 1991, however, only the data collected from approximately 1970 to 1990 was applicable for describing premine water quality conditions. Based on review of the database, it was determined that the most representative data for premine water quality in the Humboldt River was USGS data collected near Carlin (USGS Gage 10321000) and near Rye Patch (USGS

Gage 10335000). Data from other water quality stations were much less complete and were not considered in this evaluation. The Carlin site also was selected for evaluation, since it represents conditions in the upstream reach of the Humboldt River study area. The Rye Patch site was selected to represent conditions in the lower portion of the river immediately above the Lovelock agricultural development. Below the Rye Patch gage, a large percentage of the river flows are diverted for irrigation. The Humboldt River and the Army Drain are the primary sources of flow to Humboldt Lake; the Toulon Drain is the primary source of flow to Toulon Lake. Only a few samples are available to define the water quality for each of these three sources for the premine discharge period (prior to 1991).

Surface Water Quality Standards

Surface water quality standards have been established by the State of Nevada for designated beneficial uses associated with the Humboldt River. These standards are prescribed in Nevada Administrative Codes (NAC) 445A.144 and 445A.203 to 445A.208, inclusive. Beneficial uses for the Humboldt River are defined in NAC 445A.202 and include irrigation; livestock watering; contact and non-contact water recreation; industrial, municipal, and domestic supply; propagation of wildlife; and propagation of aquatic life including warm-water fisheries. Beneficial uses and water quality standards for the Humboldt River near Palisade and Woolsey are listed in Table 3-13. Water quality standards for the Palisade control point are applicable to data collected from the Humboldt River USGS Gage near Carlin (Figure 1-1). Likewise, standards for the Woolsey control point apply to data collected from the Humboldt River USGS Gage near Rye Patch (Figure 1-1).

General Surface Water Quality

Water quality data summaries from the USGS gages near Carlin and Rye Patch are listed in Table 3-14. For January 1970 through April 1991, streamflows in the Humboldt River near Carlin ranged from 5.7 to 8,130 cfs and from 0.3 to 3,010 cfs near Rye Patch. Average flow values decreased from 473 cfs near Carlin to 334 cfs near Rye Patch. The decrease in flow through the river section is due in part to diversions out of the river and evaporative losses. It is also likely that flow losses due to evapotranspiration, and sources providing additional constituent loads, contributed to an increase in the average total dissolved solids concentration calculated through the river section. Average concentrations of total dissolved solids increased from 294 milligrams/liter (mg/L) near Carlin to 548 mg/L near Rye Patch.

An average water temperature of 12°C and dissolved oxygen concentration of approximately 10 mg/L was calculated for both monitoring locations (Table 3-14). In addition to temperature and dissolved oxygen, average pH values were similar near both Carlin (8.4) and Rye Patch (8.5). As illustrated by the average values, measurements of pH were only slightly higher in the Humboldt River near Rye Patch, with two measurements during the period of record exceeding the propagation of wildlife standard (9.0).

Average concentrations of total suspended solids near Rye Patch (43.4 mg/L) were less than average concentrations near Carlin (159 mg/L). Likewise, the average turbidity was less near Rye Patch (13.6 nephelometric turbidity units [NTU]) than near Carlin (36.9 NTU). While 16 percent of the measurements near Carlin exceeded the turbidity standard of 50 NTU, no exceedences were measured

Table 3-13
Water Quality Standards for the Humboldt River at Palisade and Woolsey Control Points

Constituent	Units	Municipal or Domestic Supply	Propagation of Aquatic Life (warm water)			Propagation of Wildlife	Water Contact Recreation	Irrigation	Watering of Livestock
			Single Value Limit	1-hour Avg.	96-hour Avg.				
Physical and Aggregate Properties									
Alkalinity	mg/L as $CaCO_3$		(a)			30-130			
Color	color units	NAE							
TDS	mg/L @180°C	500[1,3]/ 1000[2,3]							3000
Temperature	°C						15-34		
Temperature (ΔT)	°C						2		
TSS	mg/L @103-5C		80[4]						
Turbidity	NTU		50						
Inorganic Nonmetallic Constituents									
Ammonia, unionized	mg/L as NH_3		0.02						
Chloride	mg/L as Cl	250							
Cyanide	mg/L as CN	0.2		0.022	0.0052				
Dissolved Oxygen	mg/L as O_2		≥5.0						
Fluoride	mg/L as F							1.0	2.0
Nitrate	mg/L as N	10							
Nitrite	mg/L as N	1.0							
pH	standard units					6.5-9.0	6.5-9.0		
ΔpH	standard units		±0.5						
SAR	ratio	8[3]						8[3]	
Sulfate	mg/L as SO_4	250							
Total Phosphorus	mg/L as P				0.1[5]				
Metals and Semi-metals[6]									
Antimony	µg/L as Sb	146							
Arsenic (total)	µg/L as As	50						100	200
Arsenic (III)	µg/L as As			342[7]	180[7]				
Barium	µg/L as Ba	2000							
Beryllium	µg/L as Be	0						100	
Boron	µg/L as B							750	5,000
Cadmium	µg/L as Cd	5		5.3[7,8]	1.3[7,8]			10	50
Chromium (total)	µg/L as Cr	100						100	1,000
Chromium (III)	µg/L as Cr			2,057[7,8]	245[7,8]				
Chromium (VI)	µg/L as Cr			15[7]	10[7]				
Copper	µg/L as Cu			22.1[7,8]	14.2[7,8]			200	500
Iron	µg/L as Fe		1,000					5,000	
Lead	µg/L as Pb	50		68.4[7,8]	1.3[7,8]			5,000	100
Manganese	µg/L as Mg							200	
Mercury	µg/L as Hg	2		2[7]	0.012				10
Molybdenum	µg/L as Mo		19						
Nickel	µg/L as Ni	13.4		1,699[7,8]	189[7,8]			200	
Selenium	µg/L as Se	50		20	5.0			20	50
Silver	µg/L as Ag		6.9[7,8]						
Thallium	µg/L as Tl	13							
Zinc	µg/L as Zn			140[7,8]	127[7,8]			2,000	25,000

[1]Applicable to Palisade control point.

[2]Applicable to Woolsey control point.

[3]Annual average.

[4]Annual median.

[5]Seasonal water quality standard from April to November.

[6]The standards for metals are expressed as total recoverable unless otherwise noted.

[7]Standard applies to the dissolved fraction.

[8]Hardness-derived standard (Nevada Administrative Code 445A.144). Values calculated assuming a hardness of 150 mg/L as $CaCO_3$.

TDS = total dissolved solids; TSS = total suspended solids; SAR=sodium adsorption ratio; NAE=No Adverse Effects.

(a) = Less than 25 percent change from natural conditions.

Source: Nevada Administrative Code 445A.144, 445A.204, and 445A.208.

Table 3-14
Humboldt River Water Quality
(Period: January 1970 through April 1991)

Constituent	Units	Carlin Gage (USGS 10321000)				Rye Patch Gage (USGS 10335000)			
		n	Min.	Max.	Avg.[1]	n	Min.	Max.	Avg.[1]
Stream Discharge	cfs	97	5.7	8130	473	121	0.3	3010	334
Physical and Aggregate Properties									
Alkalinity	mg/L as CaCO3	37	143	280	210	121	185	295	248
Hardness	mg/L as CaCO3	79	80	219	162	134	116	217	171
Temperature	°C	95	0.0	26	12	178	2.5	25	12
TDS	mg/L @ 180°C	77	178	414	294	95	407	774	548
TSS	mg/L @ 103-5 °C	75	10	2440	159	106	14	136	43.4
Turbidity	NTU	79	0.8	640	36.9	67	0.7	48	13.6
Inorganic Nonmetallic Constituents									
PH	standard units	75	7.6	8.9	8.4	149	7.6	9.6	8.5
Dissolved Oxygen	mg/L as O2	71	6.7	15.2	10.4	67	7.4	16.1	9.9
Nitrite	mg/L as N	28	<0.01	0.08	0.02	64	<0.01	0.06	0.01
Nitrate	mg/L as N	23	<0.01	0.30	0.06	62	<0.01	0.1	0.03
Phosphorous, Total	mg/L as P	79	<0.01	1.2	0.16	121	0.01	0.31	0.09
Cyanide	mg/L as CN	0	- - -	- - -	- - -	0	- - -	- - -	- - -
Chloride	mg/L as Cl	78	6.9	40	17.0	137	43	230	101.1
Sulfate	mg/L as SO4	77	11	60	33.5	130	40	100	74.5
Fluoride	mg/L as F	79	<0.1	1.3	0.5	105	0.4	1.2	0.8
Metals and Semi-metals (dissolved)									
Antimony	µg/L as Sb	0	- - -	- - -	- - -	0	- - -	- - -	- - -
Arsenic	µg/L as As	49	3	14	7.2	44	16	60	31
Barium	µg/L as Ba	48	49	140	89	31	25	82	45
Beryllium	µg/L as Be	34	<0.5	0.7	<0.5	12	<0.5	0.5	<0.5
Boron	µg/L as B	2	120	180	150	7	260	580	471
Cadmium	µg/L as Cd	48	<1	2	<1	39	<1	2	<1
Chromium	µg/L as Cr	48	<1	7	1.1	44	<1	20	2.0
Copper	µg/L as Cu	49	<1	13	3.2	44	<1	9	3.6
Iron	µg/L as Fe	49	<3	130	22	44	<3	70	15
Lead	µg/L as Pb	47	<1	10	1.9	40	<1	11	1.5
Manganese	µg/L as Mn	49	<1	56	12	43	<1	40	7.8
Mercury	µg/L as Hg	49	<0.1	0.5	<0.1	44	<0.1	1.8	0.2
Molybdenum	µg/L as Mo	34	<10	10	<10	12	<10	20	<10
Nickel	µg/L as Ni	47	<1	6	1.7	25	<1	9	2.1
Selenium	µg/L as Se	49	<1	1	<1	44	<1	1	<1
Silver	µg/L as Ag	49	<1	1	<1	32	<1	<1	<1
Zinc	µg/L as Zn	48	<3	130	11	44	<3	25	6.3

[1]For concentrations reported to be below detection, a value of one-half the detection limit was used for calculating averages. For each constituent, detection limits may have varied between sampling events.

TDS = total dissolved solids; TSS = total suspended solids; NTU = nephelometric turbidity units

n = number of concentration results available

Min. = lowest value of available results.

Max. = highest value of available results.

Avg. = calculated average of available results (calculations used one-half the detection limit for non-detected values ; if calculated average was less than the detection limit).

Source: USGS data.

near Rye Patch. Additionally, for the period of record, the total suspended solids standard near Carlin (annual median value less than 80 mg/L) was exceeded in 42 percent of the years with available total suspended solids data (1979 through 1990). No exceedences of the total suspended solids standard were measured near Rye Patch. These results likely reflect the ability of Rye Patch Reservoir to settle suspended particles from river flows.

The average total phosphorus value for the Humboldt River near Carlin (0.16 mg/L as P) was greater than the standard for the propagation of aquatic life including warm-water fisheries (0.1 mg/L as P seasonally from April through November). The average total phosphorus value near Rye Patch (0.09 mg/L as P) was less than the standard value (Table 3-14). Since phosphorous is typically associated with suspended particles in river flows, this result is consistent with the total suspended solids and turbidity results and likely reflects the settling of suspended particles in Rye Patch Reservoir.

During the period of record, metal and semi-metal concentrations in the Humboldt River near Carlin and Rye Patch were typically near or below water quality standards (Table 3-14). It should be noted that some calculated average values in Table 3-14 may overestimate actual mean concentrations. For some metals, over half of the results used to calculate average values had undetectable concentrations. Since one-half of the detection limit was used to calculate average values, the average concentration of these constituents is more a function of detection limit than of actual average river concentration. Most average constituent concentrations in the upstream river reach near Carlin were similar to average concentrations in the downstream reach near Rye Patch. The notable exceptions were arsenic and boron. Average arsenic concentrations increased from 7.2 µg/L near Carlin to 31 µg/L near Rye Patch. One dissolved arsenic measurement of 60 µg/L near Rye Patch exceeded the municipal or domestic supply standard of 50 µg/L. The average concentration of boron in the Humboldt River also increased from Carlin (150 µg/L) to Rye Patch (471 µg/L).

Humboldt Sink Water Quality. The wetlands associated with the sink are characterized by extreme wet and dry cycles. From a historical perspective, prior to the upstream agricultural development, the wetland areas completely dried up during dry periods and spread out to encompass up to 20 square miles or more during wet periods. In addition, prior to agricultural development, the area of the wetlands is estimated to have averaged about 4.5 times greater than its present size (Seiler et al. 1993). Agricultural development resulted in the construction of dikes and drains along the lower Humboldt River that drained much of the wetlands for crops. Currently, the sink area consists of Toulon Lake and upper and lower Humboldt Lakes. Water depths in the lakes typically range between 2 and 18 inches (Seiler et al. 1993).

The water quality of the Humboldt Sink wetland areas has been studied and monitored on an intermittent basis since 1987 jointly by the USGS and USFWS (Rowe et al. 1991; Seiler et al. 1993; Seiler and Tuttle 1997). As stated in the 1993 report, these studies were initiated to “determine whether the quality of irrigation drainage in and near the Wildlife Management Area (WMA), Nevada, has caused or has potential to cause harmful effects on human health or fish and wildlife, or adversely affect the suitability of water for other beneficial uses” (Seiler et al. 1993). The studies concluded that arsenic, boron, mercury, molybdenum, sodium, un-ionized ammonia, selenium, and dissolved solids exceeded biological effects levels or Nevada standards for the protection of aquatic life. Causes of contamination were identified as irrigation drainage, hydrogeologic setting, and drought (Seiler et al. 1993; Seiler and Tuttle 1997). In addition, historic ore processing along the margin of the Humboldt Sink may be the source of some trace elements in the wetlands. Specifically, two mills located along the edge of what is now Toulon Lake operated from around 1915 through the 1920s. Both plants produced tungsten and one later produced arsenic. Tailings from these operations could have been deposited or blown into what is now Toulon Lake (Seiler et al. 1993).

3.2 Impacts from Mine Dewatering and Localized Water Management Activities

3.2.1 Hydrologic Study Area

The hydrologic study area for the cumulative assessment of impacts from mine dewatering and localized water management activities encompasses approximately 2,060 square miles and includes six designated ground water basins established by the NDWR (Figure 3-1). This hydrologic study area was selected to include the area potentially affected by drawdown and mounding and localized water management activities resulting from Barrick's Goldstrike Mine and Newmont's Gold Quarry and proposed Leeville mines.

3.2.2 Dewatering and Infiltration Activities

3.2.2.1 Goldstrike Mine

The mine dewatering and water management system components for the Goldstrike Mine, Gold Quarry Mine, and proposed Leeville Mine are summarized in Section 1.2 and Tables 1-1 and 1-2. For the Goldstrike Mine, ground water pumping for mine water supply was initiated in 1987. Mine dewatering commenced in 1990 and will continue through the life of the Goldstrike Mine, currently projected to continue through the year 2010. After active mining ceases, Barrick plans to continue pumping at a rate of approximately 2,000 gpm for up to 10 years to provide for continued ore processing and reclamation activities. Pumping rates have been variable and have ranged up to approximately 69,000 gpm (average rate for 3-month period). As of the end of 1998, a total volume of 621,000 acre-feet of ground water had been pumped to achieve a maximum drawdown of approximately 1,527 feet. Current plans are to continue to lower the ground water elevation in the vicinity of the mine to 3,576 feet amsl (drawdown of 1,689 feet). Once this target is reached, pumping will continue in order to maintain the ground water at the target elevation throughout the remaining mine life. At closure, the total pumped volume will be approximately 1,085,000 acre-feet, with an estimated 564,000 acre-feet reinfiltrated to the ground water system through water management activities (including infiltration at ponds, injection, and infiltration during irrigation).

3.2.2.2 Gold Quarry Mine

Ground water pumping for water supply was initiated at the Gold Quarry Mine in 1988 (Table 1-1), with average pumping rates maintained at between about 3,000 to 4,000 gpm from 1988 through 1992 (HCI 1998b). From 1993 through 1998, the pumping rates were increased up to a maximum of approximately 20,000 gpm to allow for mining below the premining ground water elevation. As of the end of 1998, a total volume of approximately 156,000 acre-feet of ground water had been pumped to achieve a maximum drawdown of approximately 658 feet. Under the SOAPA, dewatering would continue until 2012 with peak dewatering rates of approximately 25,000 gpm, and a maximum drawdown target elevation of 3,725 feet amsl (drawdown of 1,375 feet). After active mining ceases, the mine plans to continue pumping at a rate of approximately 2,500 gpm for up to 5 years to provide for continued ore processing and reclamation activities. At closure, the total pumped volume would be approximately 595,000 acre-feet.

3.2.2.3 Leeville Mine

Under the proposed plan for the Leeville Mine, dewatering would begin in 2000 and continue through mine closure, which is projected to occur in 2018. Dewatering activities at the Goldstrike and Gold Quarry mines have resulted in an estimated 360 feet of drawdown at the proposed Leeville Mine site. Active dewatering at Leeville would lower the premining ground water elevation an additional 1,107 feet to a target elevation of 3,800 feet amsl. Estimates of dewatering indicate that the peak dewatering rate would be approximately 25,000 gpm (HCI 1998b, 1999a). A total planned pumped volume of approximately 306,000 acre-feet would be required for the Leeville Mine, with an estimated 212,000 acre-feet reinfiltrated to the ground water system as part of water management activities.

3.2.3 Impacts to Ground Water Levels

3.2.3.1 Impacts to Date (1991 - 1998)

Ground water levels have been closely monitored in the region surrounding the Goldstrike and Gold Quarry mines. The monitoring results are presented in Barrick's Boulder Valley Monitoring Plan Quarterly Reports and Newmont's Maggie Creek Basin Monitoring Plan Quarterly Reports submitted to the Nevada State Engineer and the BLM. Areas of drawdown and mounding are determined by comparison between the estimated and measured premine ground water elevations and the current ground water elevations measured at a series of monitoring wells.

The results of monitoring through the fourth quarter of 1998 were used to evaluate the ground water level changes. As of the end of 1998, over 1,500 feet of drawdown had occurred in the vicinity of the Goldstrike Mine, and over 600 feet of drawdown had occurred in the vicinity of the Gold Quarry Mine as a result of mine dewatering. In the vicinity of the proposed Leeville Mine, 360 feet of drawdown had occurred from existing dewatering operations at other mines. As illustrated in Figure 3-13 (Barrick 1999a; Newmont 1999d), a cone of depression has formed around each mine. Both cones of depression exhibit a northwest-southeast elongation. In addition, the southwest margins of the cones appear to be controlled by geologic barriers. For the Goldstrike Mine, the area with at least 10 feet of measured drawdown extends approximately 15 miles northwest-southeast and 5 miles northeast-southwest. The cone propagating from the Gold Quarry Mine extends up to approximately 16 miles northwest-southeast and 6 to 7 miles northeast-southwest. These two cones of drawdown apparently merge together beneath the Tuscarora Mountains southeast of the Carlin Mine.

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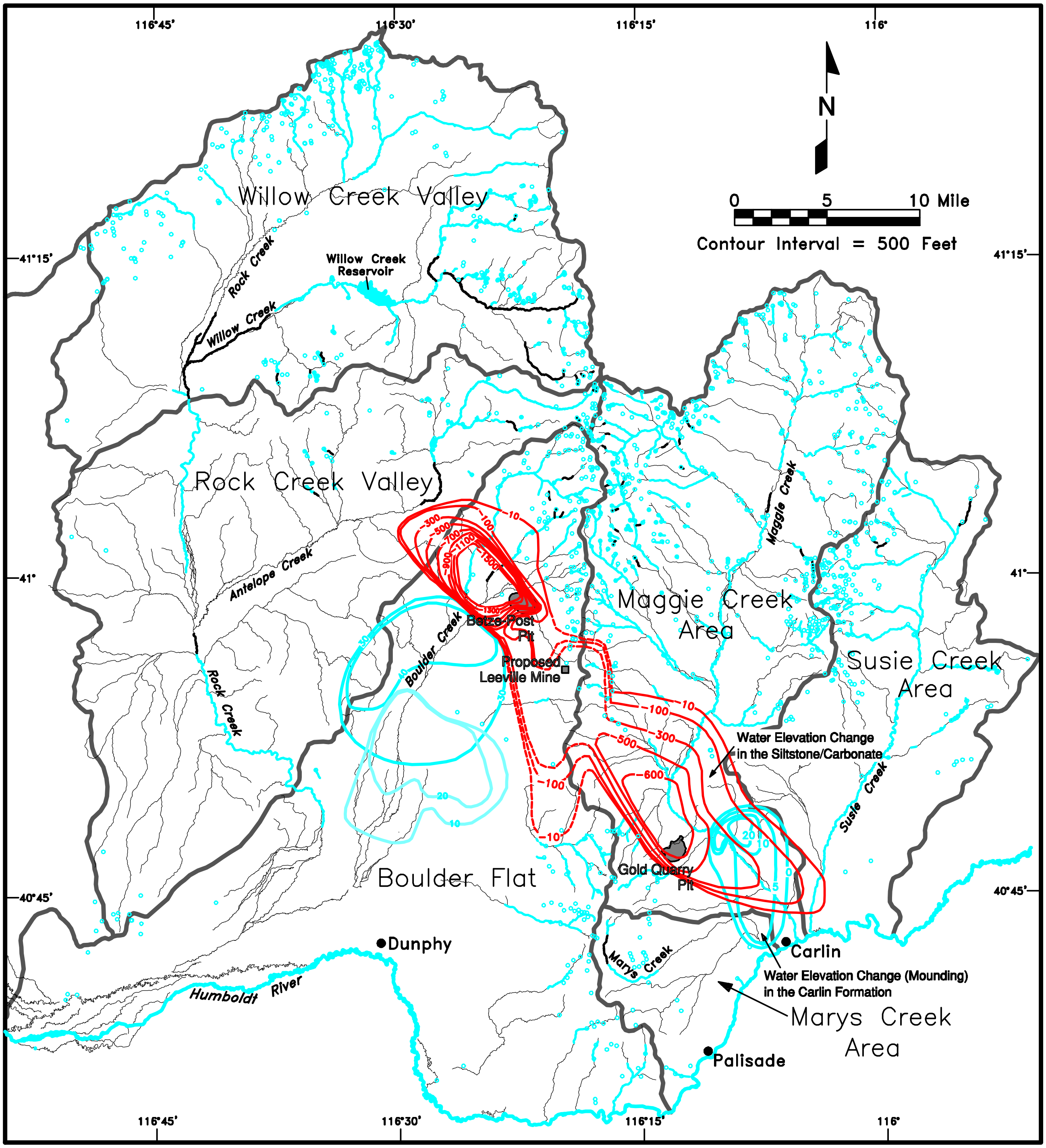

Legend

- Ground Water Basin Boundary
- Stream (Intermittent or Ephemeral)
- Perennial Steam
- Discontinuous Flowing Stream Reach
- Spring and Seep
- Water Level Decline in Area of Pumping in Feet
- Water Level Mounding in Area of Irrigation in Feet
- Water Level Mounding in Area of Infiltration/Injection in Feet

Figure 3-13

Current Drawdown and Mounding (End of 1998)

Infiltration of excess mine water from the dewatering operations has resulted in an increase in water levels, or mounding, in the upper Boulder Valley and lower Maggie Creek areas; these areas of mounding are illustrated in Figure 3-13. As of the end of 1998, water levels in the Boulder Valley region had risen up to approximately 70 feet in the rhyolite in the Sheep Creek Range and 50 feet in the alluvium in upper Boulder Valley. Barrick currently plans to continue to infiltrate excess mine water in the upper Boulder Valley area through the end of mining.

Barrick began delivering water to the TS Ranch Reservoir in May 1990. Monitoring of discharge quantities and reservoir levels indicated that the reservoir was not filling as initially anticipated due to the appearance of the fracture described in Section 2.2.3. A large percentage of the water that flowed into the reservoir seeped through the fracture in the floor of the reservoir and flowed into the rhyolite formation. In 1992 and 1993, seepage from the reservoir apparently resulted in three new springs (referred to as Sand Dune, Knob and Green springs) in the northeastern portion of Boulder Flat, approximately 5 miles south of the TS Ranch Reservoir. The location of TS Ranch Reservoir and Sand Dune, Knob, and Green springs are shown in Figure 3-1. Barrick continued to deliver water to the TS Ranch Reservoir, and the majority of the water infiltrated into the rhyolite formation underlying the reservoir until early 1996. The combined flows from these springs during this period ranged up to a peak of approximately 30,000 to 35,000 gpm in 1996. From April 1996 through 1998, water management activities were modified such that excess mine water no longer seeped through the fracture. As a result, the flows in the springs diminished to approximately 5,000 gpm by the end of 1998.

Newmont stores excess mine dewatering water in Maggie Creek Reservoir (Figure 3-1) and discharges water to the Humboldt River via lower Maggie Creek. Seepage from Maggie Creek Reservoir and through infiltration along portions of lower Maggie Creek has resulted in an increase in water levels in the lower Maggie Creek Basin. Current monitoring in Maggie Creek Basin shows that water levels increased by up to 45 feet from 1992 to the end of 1998 directly south of Maggie Creek Reservoir in the Carlin Formation. A zone with an approximately 5-foot increase in water levels stretches from the reservoir to just northwest of the town of Carlin (Figure 3-13).

3.2.3.2 Predicted Future Impacts (Post-1998)

Numerical Modeling Predictions

Both Barrick and Newmont have developed numerical ground water models that encompass the regional hydrologic study area. Each model was used to simulate the combined or cumulative hydrologic effects resulting from dewatering and water management activities at all three mines (Goldstrike, Gold Quarry, and Leeville). An overview of the model set-up and results of the cumulative simulations for different time periods are provided in Appendix D.

Barrick's numerical model uses the USGS modular three-dimensional, finite-difference ground water flow model MODFLOW (McDonald and Harbaugh 1988) to simulate mine dewatering and water management activities. The model design, modifications, calibration, simulations, and sensitivity analyses are presented in MMA (1998). Newmont's numerical hydrologic model uses MINEDW, a proprietary code that has been tested and verified by Sandia National Laboratory (1998). MINEDW is a three-dimensional finite-element code developed by HCI to simulate mine dewatering. The model design, calibrations, and sensitivity analyses are provided in HCI (1999b).

The numerical flow models developed by Barrick and Newmont were used to provide separate predictions of the cumulative drawdown of the ground water surface at the end of mining and in the postmining period. Results of the model simulations for selected periods are presented in Appendix D. It is important to understand that the actual hydrogeologic conditions in the vicinity of the mines and surrounding region are complex. Regional ground water flow models are based on a simplified conceptual understanding of the hydrostratigraphic and hydrostructural conditions, recharge and evapotranspiration processes, and ground water flow patterns. It is possible that unknown or undetected conditions may exist, such as hydraulic barriers or zones of unusually high permeability, that could influence the future drawdown patterns, particularly in the post-dewatering period. The models assumed that precipitation amounts and patterns observed over the last several decades are representative of future conditions. For long-term predictions (several decades to hundreds of years), there is uncertainty regarding future climatic conditions. Despite these limitations, numerical models based on an accurate conceptual model of the hydrologic and hydrogeologic system, and calibrated to monitored steady state and transient ground water elevations, represent the best available tool for predicting the general areal extent, magnitude, and timing of drawdown and recovery that should be anticipated in the future from the combined mine dewatering activities. (Note: both models are recalibrated annually to monitoring results.)

Both models predict that the extent and magnitude of the cone of drawdown would vary over time and persist for an extended period postmining (see Appendix D, Figures D-6, D-7, and D-8, for the Barrick model, and Figures D-13, D-14, and D-15, for the Newmont model). As a result of conceptual differences in hydrogeologic conditions, including hydraulic parameters, each model produces unique results; however, both models are physically reasonable interpretations, and the BLM considers both of them acceptable. Both models predict that the cone of drawdown would continue to expand and reach a maximum (in most directions) at approximately 100 years postmining.

For the cumulative analysis, the area that is predicted to experience a change in ground water elevation of 10 feet or more due to mine dewatering and mine water management activities was selected as the area of potential concern regarding impacts to water resources. Changes in the water table elevation of less than 10 feet were generally not considered in the analysis because these changes would probably be indistinguishable from natural seasonal and annual fluctuations in ground water levels. Barrick's and Newmont's calibrated models were used to estimate the change in ground water levels over regular time intervals throughout the future mining and postmining period up to final recovery. The results from both models were then combined to illustrate the predicted maximum extent of 10-foot drawdown irrespective of time, as presented in Figure 3-14 (Barrick 1998c; Newmont 1999a).

3.2.4 Impacts to Perennial Springs and Streams

Drawdown from dewatering at the Goldstrike, Gold Quarry, and proposed Leeville mines would lower the ground water levels in the surrounding region, as described above. In the vicinity of the projected drawdown area, the late summer to fall flows (or baseflow) in individual springs and perennial stream reaches are supported by discharge from either the regional ground water aquifer system or from more isolated or

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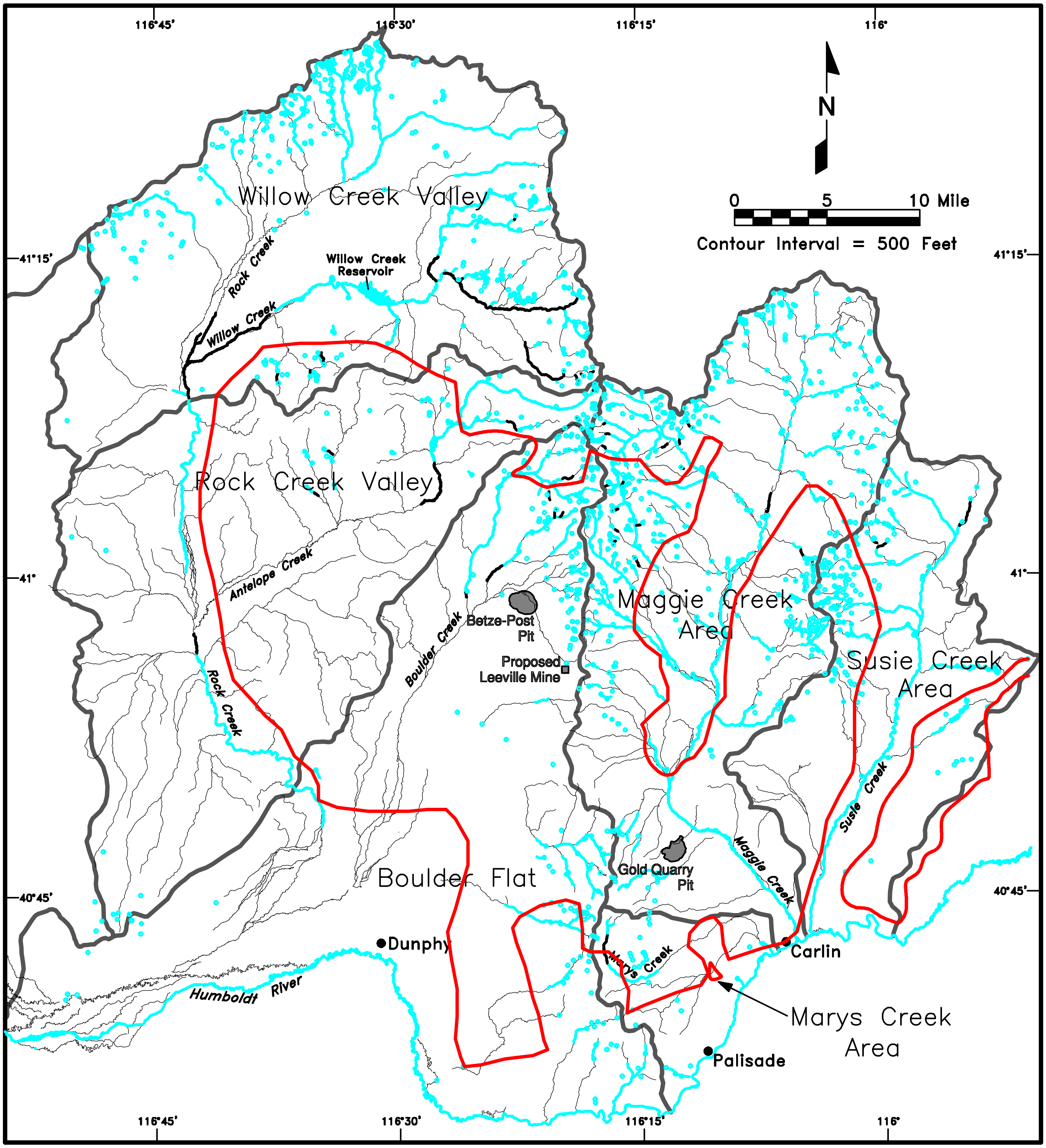


Legend

- Ground Water Basin Boundary
- Maximum Extent of 10-foot Drawdown Contour
- Stream (Intermittent or Ephemeral)
- Perennial Steam
- Discontinuous Flowing Stream Reach
- Spring and Seeps

Figure 3-14

Predicted Maximum Extent of 10-Foot Drawdown Relative to Perennial Waters

perched aquifers residing above the regional ground water system. A reduction in the ground water levels from mine-induced drawdown could potentially reduce the discharge to some perennial sources and reduce the length of perennial reaches, eliminate springs, and reduce the associated riparian/wetland areas of perennial water sources associated with the regional ground water system.

3.2.4.1 Impacts to Date

Barrick currently monitors selected spring sites and surface water gages for potential drawdown impacts. Several springs located both within and outside of the current 10-foot drawdown area have dried up or have shown a reduction in flow (ABC 1999). It is possible that some of these effects may be related to mine dewatering. It also is likely that springs other than those currently included in the annual monitoring program also have been impacted by mine dewatering. The flow and vegetation in Brush Creek, a tributary to Rodeo Creek, have changed substantially since 1993, indicating that this drainage has been impacted by mine dewatering (ABC 1997). No additional impacts to streams or springs have been recorded on the western side of the Tuscarora Mountains.

Quarterly, semiannual, and annual surveys of selected springs have been conducted since 1990 by Newmont (1999c). These surveys include flow measurements, water quality sampling analysis, and a vegetation description. No measurable effects on monitored spring flows have been recorded as a result of Gold Quarry dewatering through Fall 1998.

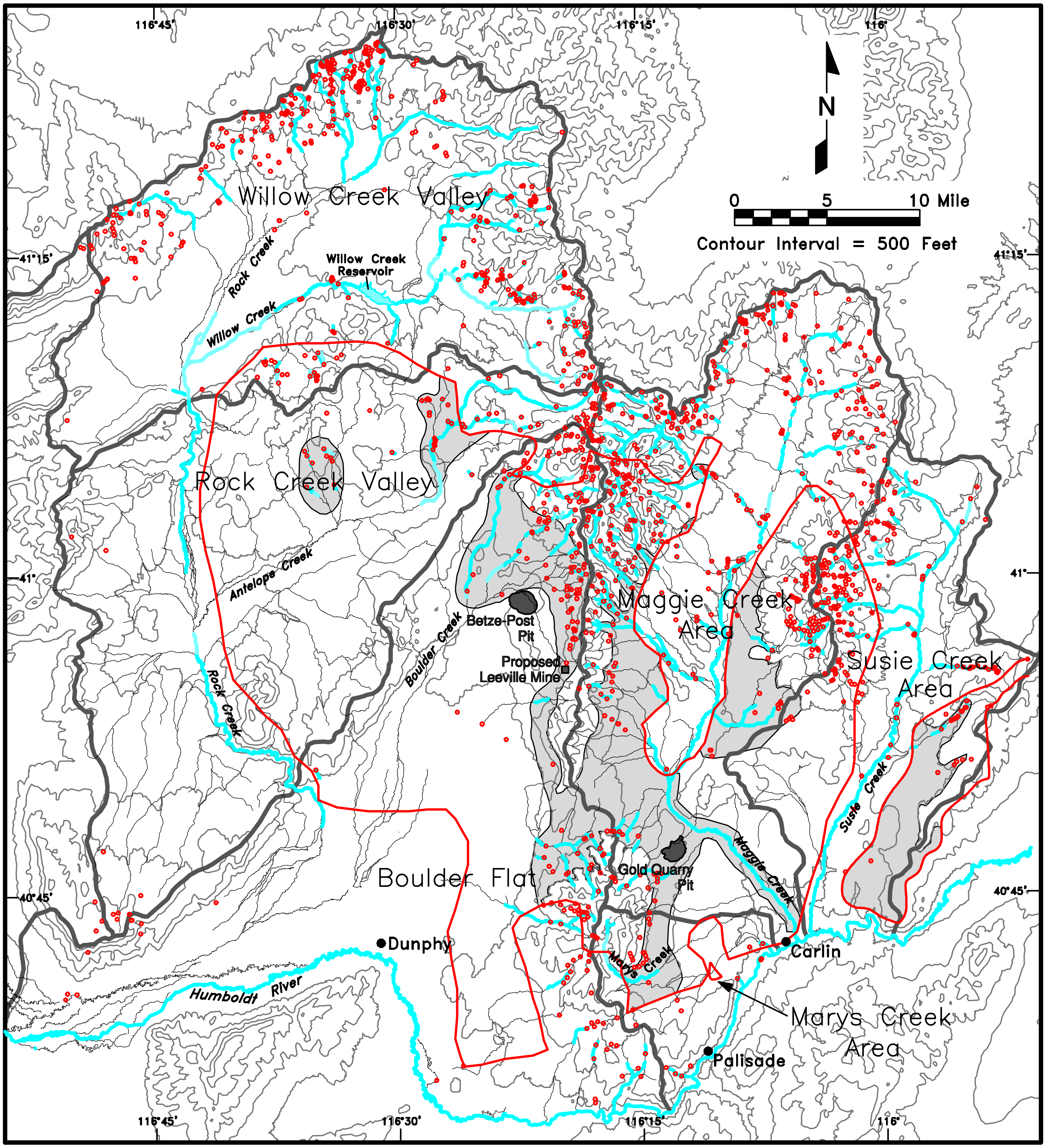
3.2.4.2 Projected Future Impacts

As discussed previously, both the Barrick and Newmont models were used to predict ground water drawdown over time resulting from mine dewatering. The results from both models were combined to illustrate the maximum extent of the 10-foot drawdown contour irrespective of time. This area and the identified springs, seeps, and perennial stream reaches within the hydrologic study area are illustrated in Figure 3-15. As listed in Table 3-15, there are 537 springs and seeps located within the predicted combined

Table 3-15
Summary of Springs Within the Drawdown Area

Ground Water Basin	Number of Monitored Springs Showing Flow Reduction to Date	Total Number of Known Springs and Seeps Within Cumulative Drawdown Area	Number of Known Springs and Seeps (Within Cumulative Drawdown Area) Located in Areas Where Surface Waters Potentially Could Be Impacted By Drawdown [1]
Willow Creek Valley	0	22	0
Rock Creek Valley	0	31	27
Boulder Flat	9	122	74
Maggie Creek	0	217	48
Marys Creek	0	19	11
Susie Creek	0	126	22
Total	**9**	**537**	**182**

[1]See Figure 3-15.



Legend

- Ground Water Basin Boundary
- Cumulative Drawdown Area (≥10 Feet of Drawdown)
- Perennial Steams
- Discontinuous Flowing Stream Reach
- Spring and Seep
- Areas where Perennial Waters could Potentially be Impacted by Drawdown[1]
- Areas where Perennial Waters have a Low Probability of Being Impacted by Drawdown[1]

Note: [1] Does not include potential impacts to perennial waters located outside the cumulative 10-foot drawdown contour.

Figure 3-15

Potentially Impacted Perennial Waters Within the Cumulative Drawdown Area

cumulative 10-foot drawdown area. Of these, 182 springs and seeps are located in areas where perennial surface waters could potentially be impacted by drawdown.

Individual springs, seeps, and perennial stream reaches are supported by discharge from either the regional ground water aquifer system or from more isolated or perched aquifers residing above the regional ground water system (or by some mixture of each of these water types). Only those perennial sources that are hydraulically connected to the regional ground water system would potentially be impacted by mine-induced drawdown. Therefore, impacts to individual springs and perennial stream reaches that are supported entirely by perched (or hydraulically isolated) aquifers located above the regional ground water system are not anticipated. Conversely, perennial waters that are hydraulically connected to the regional ground water system could be impacted.

The actual impacts to an individual spring or stream reach would depend on the source (or sources) of ground water that sustains perennial flow and the actual mine-induced drawdown that occurs at the site. The interconnection (or lack of interconnection) between the surface waters and deeper ground water sources is controlled in large part by the geology of the area. Considering that the geology of the region is complex and variable over the region, and that the area contained within the 10-foot drawdown contour encompasses an area of more than 800 square miles, it is not possible to conclusively identify specific springs and seeps that would or would not be impacted by future mine-induced drawdown. However, based on the general depth to ground water measured in observation wells throughout the region (Figure 3-16), and the geochemistry and isotopic signature of representative springs in different regions, several generalizations can be made regarding the source of perennial waters and the relative likelihood of impacts for different regions.

Numerous springs support perennial stream segments in the Tuscarora Mountains. On the eastern side of the range, spring discharge supports perennial flow in the headwater tributaries of Maggie Creek including, from north to south, Beaver Creek, Little Beaver Creek, Coyote Creek, Little Jack Creek, Indian Creek, Cottonwood Creek, Lynn Creek, and Simon Creek. On the western side of the range, spring discharge supports perennial flow in the headwaters of Willow Creek, Rock Creek, Antelope Creek, Boulder Creek, Bell Creek, and Brush Creek. According to the current model projections, mine-induced drawdown is projected to extend into these areas. Several studies suggest that springs and perennial stream reaches in this region can be separated into two distinct types based on elevation: 1) higher elevation springs, seeps, and spring-fed streams supported by perched or localized aquifers such that there is not a saturated continuity between the shallow ground water system and the deeper, more regionally extensive aquifer system; and 2) lower elevation springs, seeps, and perennial steams that are potentially influenced in part by flow from a deeper, regionally extensive aquifer system (Balleau Groundwater Consulting and Leggette, Brashears, & Graham, Inc. 1992; Zimmerman 1992a; Desert Research Institute 1998a). The distinction between these two different perennial sources is supported by water chemistry data, stable isotope ratios, tritium concentrations, and water-level data from wells completed in the Tuscarora Mountains (Desert Research Institute 1998a). Balleau Groundwater Consulting and Leggette, Brashears, & Graham, Inc. (1992) inferred that the transition between the two perennial source types occurs at an elevation of approximately 6,000 feet. Although this is a reasonable elevation for use in delineating areas of potential impacts, it is important to understand that more extensive spring chemistry and isotope data (RTi 1994) and water-level data from wells (Desert Research Institute 1998a) suggest that this transition elevation may be variable from area to area.

Hydrogeologic conditions, spring and seep surveys, elevations, and geochemistry for representative springs were considered to identify areas within the maximum predicted 10-foot contour that could potentially be impacted by mine dewatering. The identified areas where spring and seep flows could be impacted are shown in Figure 3-15. These areas include springs, seeps, and perennial reaches located on the eastern and western side of the Tuscarora Mountains located at or below an approximate elevation of 6,000 feet. In the region surrounding the Betze-Post Pit (i.e., Bell Creek, Brush Creek, and Rodeo Creek drainages), the potentially impacted area includes some springs above 6,000 feet. These potential impacts in the Bell, Brush, and Rodeo Creek drainages reflect local dewatering activities (i.e., dewatering wells located in the Vinini Formation east of the Post fault). Results of monitoring to date, water chemistry, and tritium concentrations suggest that some perennial waters in this area represent older ground water discharged from a deeper, more regional source.

Additional springs, seeps, and perennial stream reaches occur in the western portion of the hydrologic study area (west of the Tuscarora Mountains), in the Antelope Creek and Willow Creek drainages. Areas of potential concern include several springs, seeps, and the spring-fed perennial reaches of upper Antelope Creek and its tributaries, and include the lower portion of North Antelope Creek and Squaw Creek. The springs in these specific areas generally have intermediate to high ionic concentrations and very low tritium concentrations (RTi 1994); this ionic and isotopic signature suggests that these waters are older and probably derived from a more regional ground water source. Water-level data from monitoring wells (Figure 3-16) also indicate that the regional ground water levels are relatively shallow in some of these areas. Therefore, it is assumed that drawdown would potentially impact perennial flows in specific regions in the Rock Creek Hydrologic Basin, as shown in Figure 3-15 (JBR 1990a, 1992b; RTi 1994; Newmont 1999a,c; MMA 1998; USGS Quads; Barrick 1998c). Other perennial waters within this region are interpreted to have a low probability of impact since representative springs in these areas generally have very low ionic concentrations and high tritium concentrations suggesting that these waters are very young and derived from shallow localized flow.

The highlands area located to the west and southwest of the Gold Quarry Mine includes the southern portion of the Tuscarora Mountains and the Marys Mountain area (Figure 2-1). For this discussion, this area is informally referred to as the Marys Mountain block. As illustrated in Figure 3-15, numerous springs are located within the Marys Mountain block; however, water-level data from bedrock wells in this area are sparse. As shown in Figure 3-16, three monitoring wells are located within or near the flanks of the mountain block. These three wells indicate that ground water levels are at an elevation of approximately 6,000 feet and are near-surface or artesian (with measured water pressures equivalent to water-level elevations above the ground surface). A series of springs that issue from the bedrock along the eastern flank of the Marys Mountains occur at an elevation of approximately 6,000 feet, similar to the water-level elevations measured in the nearby wells. The water quality of the springs and wells is a similar calcium bicarbonate type with relatively low concentrations of total dissolved solids and neutral to slightly alkaline pH. Limited oxygen isotope data from several of these springs indicate a relatively fresh water and similar recharge source (Newmont 1999c).

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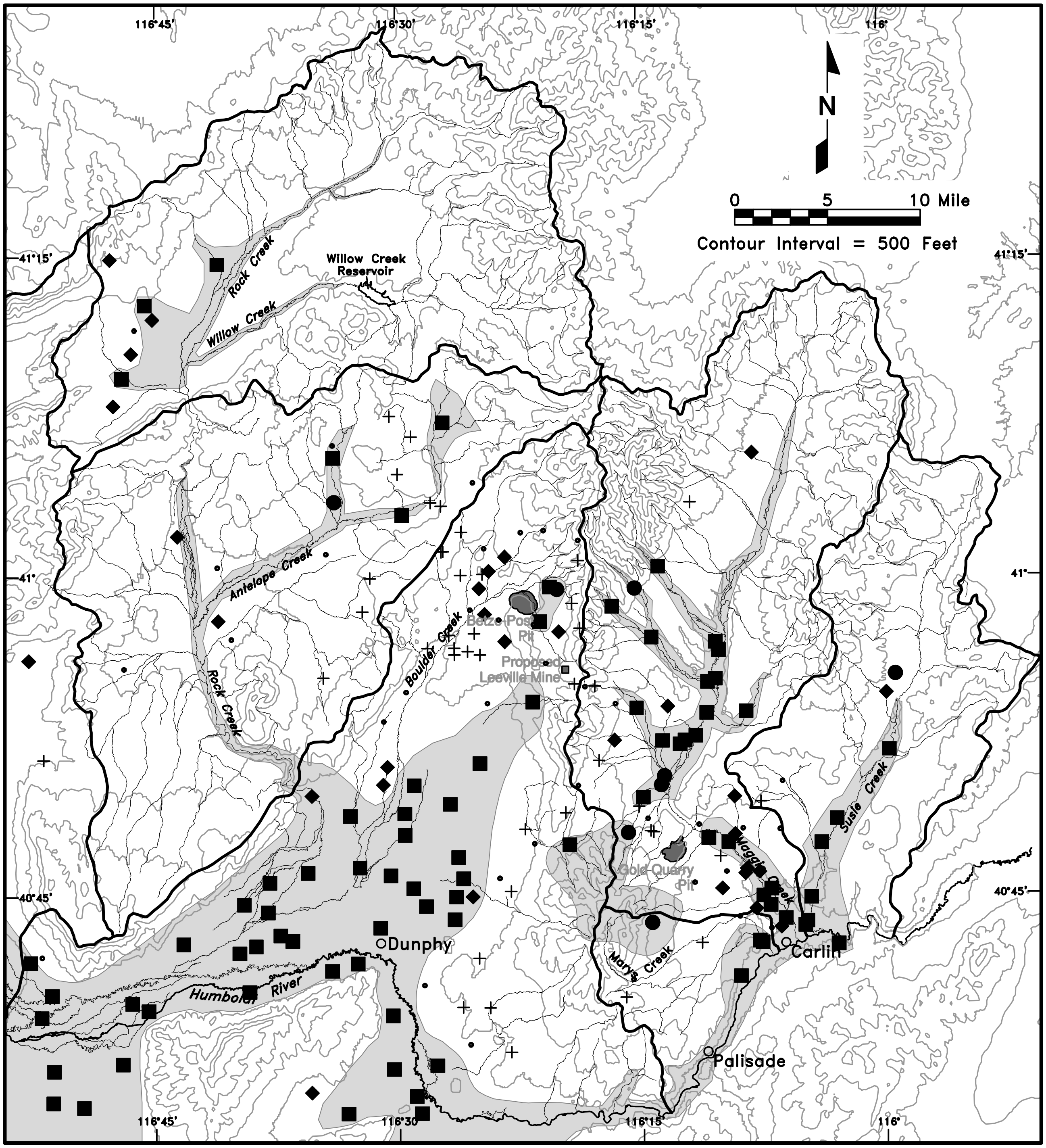

Legend

- Ground Water Basin Boundary
- Stream
- Water Depth (≤50 Feet)
- Water Depth (>50 Feet)

Monitoring Wells (Depth to ground water - Feet)

- ● Well (Artesian)
- ■ Well (1 to 50)
- ◆ Well (51 to 100)
- • Well (101 to 200)
- + Well (>201)

Notes: Depth to Ground Water is inferred from:
1) depth to water measured in wells and
2) topography
3) phreatophyte distribution

Excludes localized perched aquifers

Given the scale of this map, monitoring wells in the vicinity of the mine is not shown due to the density

Figure 3-16

Inferred Depth to Ground Water (Premine)

Ground water flow is assumed to be complex across this area. It is conceivable that the spring domain within the Marys Mountain block could be controlled by either upward leakage from a deeper confined bedrock system or by localized perched ground water systems or some combination of the two. Since mine dewatering is predicted to eventually lower the heads in the deep bedrock system underlying the Marys Mountain block area, several springs in this area potentially could be impacted by drawdown. This includes the series of springs located along the eastern flank of the Marys Mountains, discussed in the previous paragraph, and springs located below an elevation of 6,000 feet. The potential for impacts to other springs above 6,000 feet elevation is considered low. To date, no impacts to springs in the Marys Mountain block area have been recorded.

Impacts to perennial waters in the Independence Mountains and Adobe Range are based on the assumptions that springs located above an approximate elevation of 6,000 feet have a low probability of impact. This assumes that springs above 6,000 feet are likely to be supported by perched, or hydraulically isolated, and localized aquifers that are not connected to the regional ground water system. Although this is a reasonable assumption for this regional analysis, it is important to emphasize that this 6,000-foot transition elevation is likely to be variable from area to area and dependent on site-specific conditions.

Model Simulated Baseflow Reductions

Flows in some stream reaches could potentially be reduced as a result of mine-induced drawdown from the Goldstrike, Gold Quarry, and Leeville mine operations. HCI's report *Prediction of Potential Hydrologic Impacts of Dewatering Operations Along Northern Carlin Trend, May 1999* (HCI 1999a), presents model simulations of baseflow reductions for selected stations on Rock, Boulder, Marys, Maggie, and Susie Creeks. Baseflow is the ground water component of surface water flow. In the late summer to fall period, when precipitation is low, perennial streamflow is sustained by the discharge of ground water. Baseflow is distinct from the contributions to streamflow associated with runoff from snowmelt or precipitation events. The locations of the stations used by HCI for the simulations of baseflow changes are presented in Figure 3-17. As shown in Figure 3-17, stations on Maggie, Susie, and Rock creeks are located outside the predicted 10-foot drawdown contour.

In is important to understand the uncertainty associated with long-term simulations of changes in baseflow (or ground water discharge) in steams distributed over a large region. The regional numerical ground water model developed by HCI encompasses over 2,000 square miles. Regional models are based on a conceptual model that represents a simplified and generalized understanding of the hydrogeologic and hydrologic conditions over large areas. As presented in Appendix D, the HCI model and the Barrick regional hydrology model are based on different interpretations of the regional conditions, and although both models are calibrated to historic water levels, each model predicts a different pattern of drawdown. These differences illustrate the uncertainty regarding the model-predicted extent of the drawdown cone in the postmining period. This is an important consideration since simulations of baseflow changes are closely linked to predictions of drawdown.

Another source of uncertainty is the hydraulic interconnection between the deeper regional ground water system and perennial streams. Because of the simplified assumptions in the model and unknown conditions

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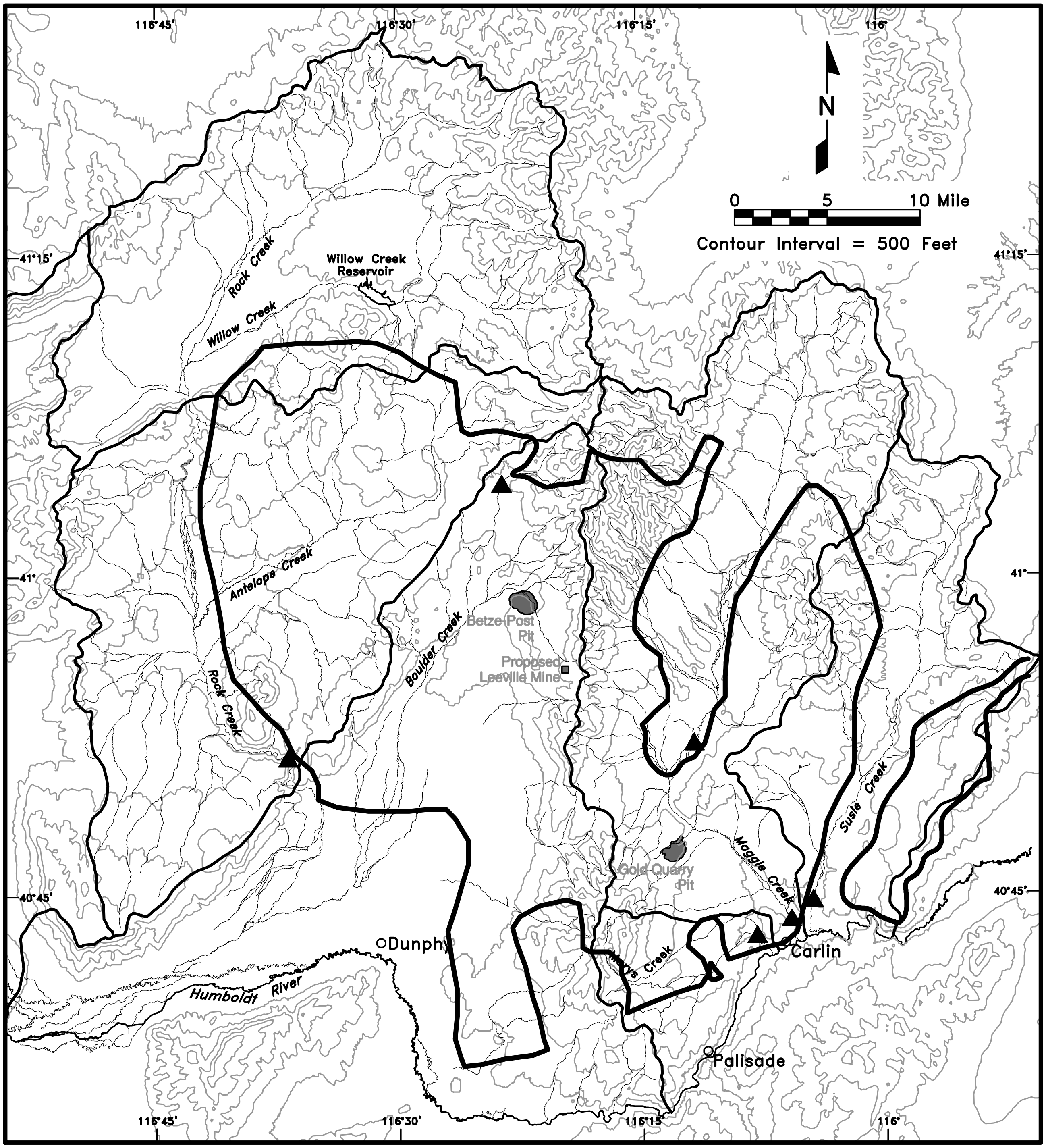


Legend

Ground Water Basin Boundary

Stream

Cumulative Drawdown Area (≥10 Feet of Drawdown)

▲ Location of Baseflow Predictions

Figure 3-17

Location of Baseflow Predictions

beneath the streams, the baseflows may not change as predicted by the model. In addition, a key parameter used to define the ability of the streambed to transmit water (called “leakance”) was assumed to be the same for all streams (HCI 1999c). In actuality, this value is likely to vary among streams and among different segments of an individual stream. It is also important to note that for stations on lower Rock Creek, upper Boulder Creek, and upper Maggie Creek, the premine baseflows were simulated by the model (HCI 1999c). Therefore, the actual baseflows in these streams are unknown as flow monitoring data are not available for these stations.

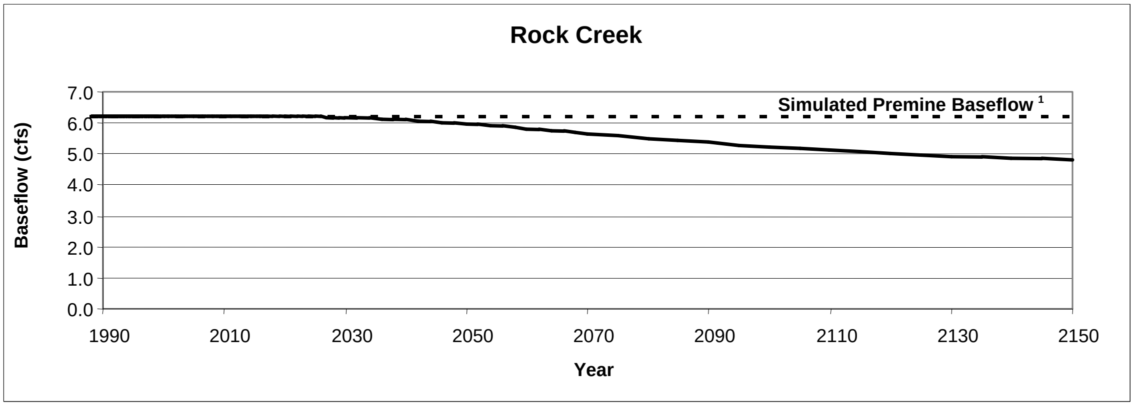
HCI’s simulations of stations on Rock, Boulder, Maggie, Marys, and Susie creeks (shown in Figure 3-17) are presented in Figures 3-18 and 3-19. The simulations indicate that if the drawdown propagates outward in the postmining period in the patterns that the model predicts, and if the deeper aquifers are hydraulically connected to the streams as conceptualized, some reduction in baseflow could occur. For Rock Creek, the modeled data assume an initial (premine) baseflow of 6.4 cfs, and between the end of mining for Goldstrike and Gold Quarry (year 2012) and year 2150, baseflow could gradually be reduced to 4.8 cfs (HCI 2000a). Boulder Creek has a model-simulated initial (premine) baseflow of 1.6 cfs that could gradually be reduced to 1.5 cfs by the year 2100 and then recover to premine baseflow conditions in the postmining year 2100 period (HCI 2000a).

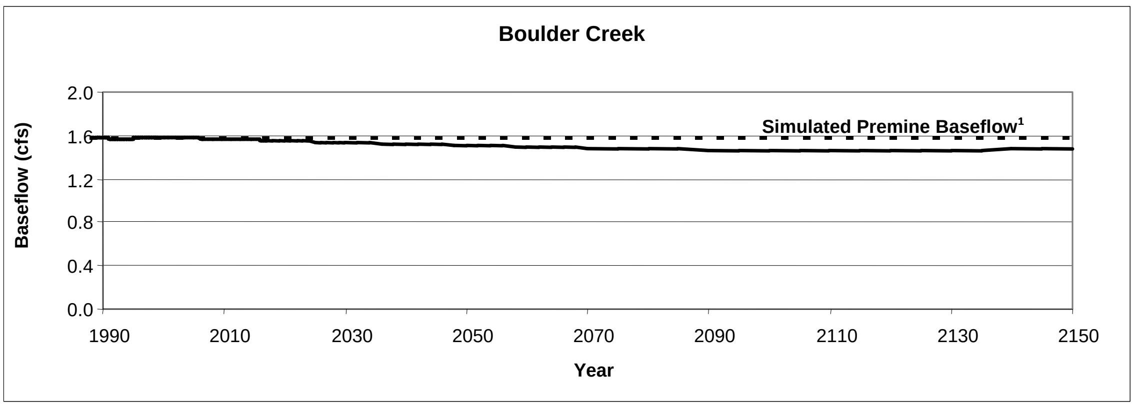
For Marys Creek, the estimated average initial (premine) baseflow computed from measurements at stream gages is 2.7 cfs, with a model-simulated baseflow of 2.8 cfs (HCI 1999c). The model simulations indicate that Marys Creek baseflows could gradually be reduced between 2011 and 2040 to 0.9 cfs, then gradually recover to premine conditions after 2070 (HCI 2000a). Baseflow in Marys Creek consists predominantly of discharge from the Carlin Cold Spring (Maurer et al. 1996). It is inferred that if these simulated drawdown patterns are realized, both the Carlin Cold Spring and Carlin Hot Spring could be impacted since they are both located in the same region.

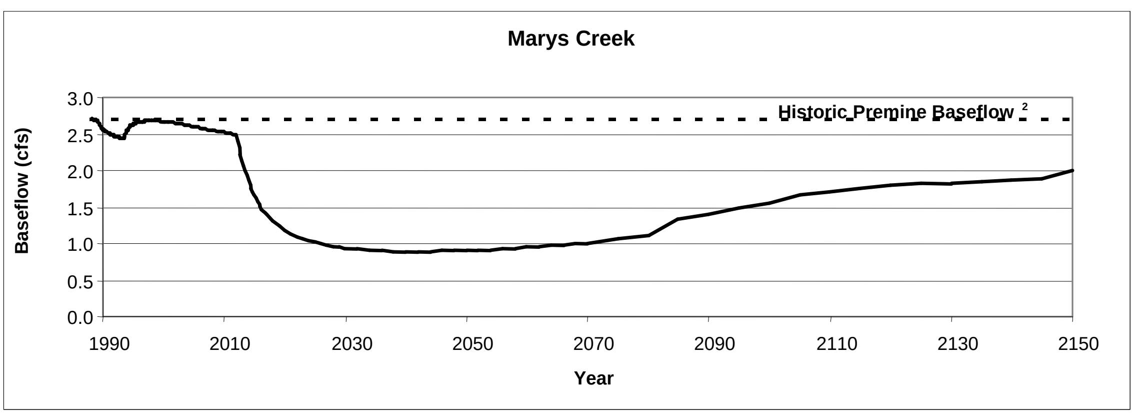
In upper Maggie Creek, the model-simulated initial (premine) baseflow of 5 cfs could gradually be reduced to 4.2 cfs by 2060 and then gradually recover from 4.2 to 4.9 cfs in the postmining 2060 year period (HCI 2000a). Based on streamflow measurements, the lower Maggie Creek station has an estimated long-term average premine baseflow of 1.3 cfs, and the model-computed premine baseflow is 1.8 cfs (HCI 1999c). The model simulations indicate that lower Maggie Creek could dry up shortly after mine discharge is discontinued and not recover (HCI 1999a, 2000a)

Susie Creek has a long-term average baseflow computed from stream gage measurements of 0.7 cfs, and a model-simulated premine baseflow of 11 cfs (HCI 1999c). The model simulations indicate that Susie Creek at this location could experience a reduction in baseflow starting in 2004 that eventually eliminates all baseflow between 2030 and 2070. If this were to occur, similar reductions in flow could potentially occur in the lower segment of Susie Creek. After 2070, the simulations indicate that Susie Creek baseflow would gradually recover to near premine conditions (HCI 2000a).

In summary, model simulations suggest that reductions in baseflow could occur in lower Rock Creek, Boulder Creek, Marys Creek, upper and lower Maggie Creek, and lower Susie Creek. However, because of the limitations inherent in hydrologic modeling and the uncertainty regarding the hydrologic interconnection





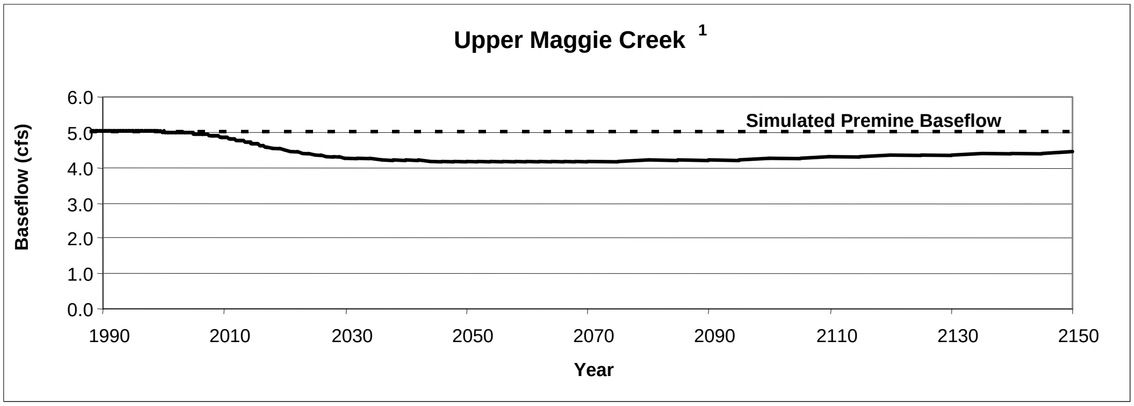


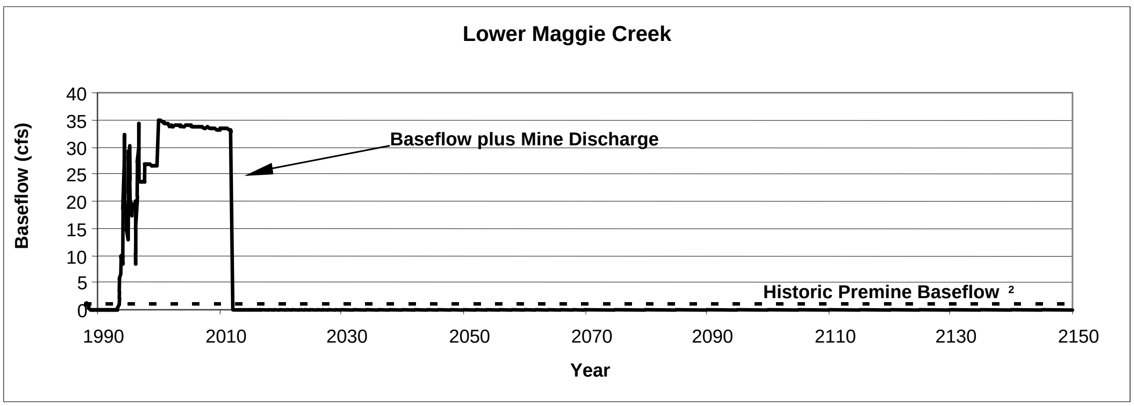
[1] Streamflow measurement data not available at this location; model data used to simulate average premine baseflow, and potential changes in simulated baseflow.

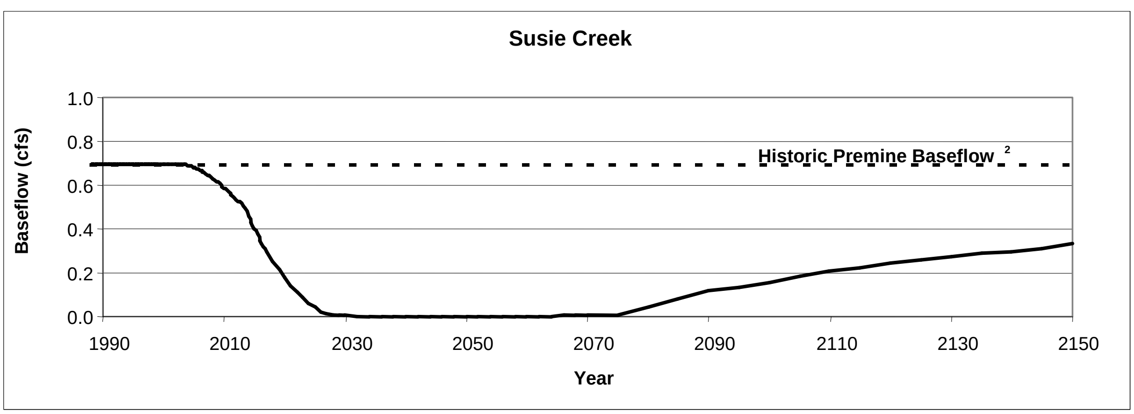
[2] Long term average baseflow (premine).

Figure 3-18

Model Simulated Changes in Baseflow Rock Creek, Boulder Creek, and Marys Creek







[1] Streamflow measurement data not available at this location; model data used to simulate average premine baseflow, and potential changes in simulated baseflow.

[2] Long term average baseflow (premine).

Figure 3-19

Model Simulated Changes in Baseflow Maggie Creek and Susie Creek between the streams and the regional ground water system, the actual areal extent and magnitude of impacts to perennial waters are uncertain.

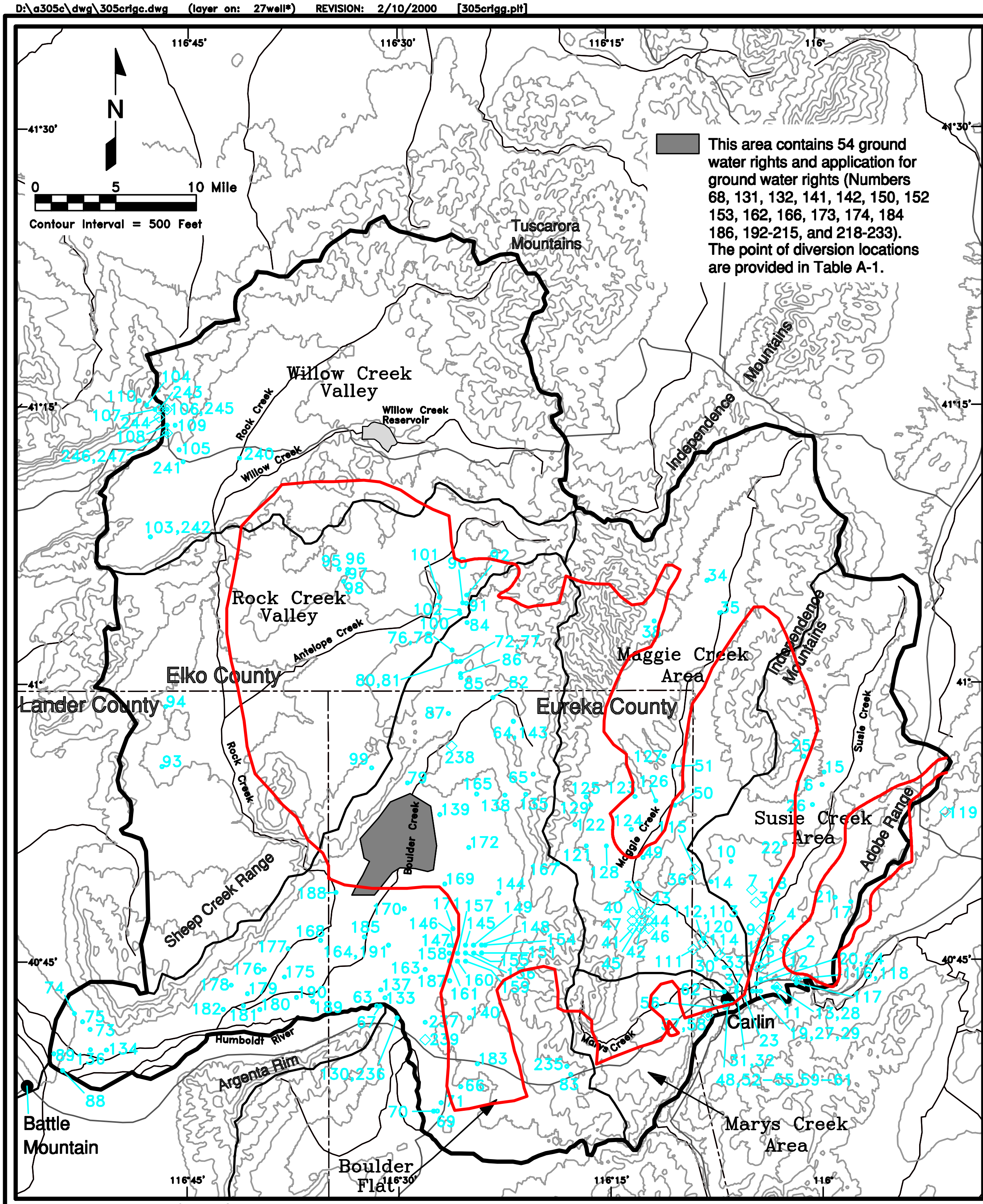
The cumulative mine-induced drawdown would potentially reduce flows in the Humboldt River, particularly in the postmining period. Potential baseflow reductions in the Humboldt River during the postmining period are addressed in Section 3.3.

3.2.5 Impacts to Ground Water Rights

To evaluate potential impacts, the future drawdown predictions were compared to the point of diversion locations reported in Appendix A-1 and summarized in Section 3.1.2.1. Appendix A-1 includes 1) ground water rights with active water rights status, 2) applications for ground water rights on file with the State Engineer, and 3) other known wells. For this inventory, all rights and applications owned by Barrick Goldstrike Mines, Inc. and Newmont Gold Company or their affiliates were included except for water rights classified as mining and milling. Since water rights are not necessary for residential or ranch domestic wells, the inventory does not include all domestic wells that may exist within the regional study area. As shown in Figure 3-20 and summarized in Table 3-16, the results of the modeling indicate that water levels in 115 underground water rights with current *permit*, *certificate*, or *vested* status potentially could be lowered by at

Table 3-16
Summary of Ground Water Rights Within the Cumulative Drawdown Area

Ground Water Basin	Domestic	Irrigation	Mining/ Milling	Municipal	Stock	Other	Total
Ground Water Right with Current *Permit*, *Certificate*, or *Vested* Status							
Susie Creek Area	0	0	0	0	6	0	**6**
Maggie Creek Area	0	6	0	1	9	0	**16**
Marys Creek Area	0	3	0	3	1	3	**10**
Boulder Flat	0	39	10	0	21	2	**72**
Rock Creek Valley	0	0	10	0	1	0	**11**
Willow Creek Valley	0	0	0	0	0	0	**0**
Total	**0**	**48**	**20**	**4**	**38**	**5**	**115**
Applications for Ground Water Right and Other Known Wells							
Susie Creek Area	0	6	0	0	0	0	**6**
Maggie Creek Area	3	0	0	0	2	9	**14**
Marys Creek Area	0	0	0	0	0	0	**0**
Boulder Flat	0	12	0	0	2	0	**14**
Rock Creek Valley	0	0	0	0	0	0	**0**
Willow Creek Valley	0	0	0	0	0	0	**0**
Total	**3**	**18**	**0**	**0**	**4**	**9**	**34**



Legend

- Study Area
- Ground Water Basin Boundary
- Predicted Maximum Extent of 10-foot Drawdown
- Stream
- County
- 70 • Point of Diversion for Ground Water Right with Current Permit, Certificate, or Vested Status
- 47 ◇ Listed Point of Diversion for Applications for Ground Water Right (Application, Ready for Action, and Ready for Action Protested), and other known well locations

See Table A-1 for details

Figure 3-20

Predicted Maximum Extent of 10-foot Drawdown Relative to Ground Water Rights, Application for Ground Water Rights, and Other Known Wells

least 10 feet during the mine life or in the postmining period as a result of Barrick and/or Newmont ground water pumping. The point of diversion locations listed for 34 applications for ground water rights also are located within the cumulative 10-foot drawdown contour. If these applications are eventually granted, these new water rights also potentially could be impacted by drawdown. In addition, there are five known wells (without water rights status) located within the identified cumulative drawdown area.

Specific impacts to individual wells would depend on the well completion, including pump setting, depth, yield, and premining static and pumping water levels. Lowering the water levels in these water supply wells would potentially reduce yield, increase pumping cost, or if the water level were lowered below the pump setting or below the bottom of the wells, the well would become unusable.

3.2.6 Impacts to Surface Water Rights

A potential reduction in the baseflow of perennial springs and streams could affect surface water rights. As shown in Figure 3-21 and listed in Table 3-17, there are 45 surface water rights with current *permit*, *certificate*, or *vested* status within the drawdown area. A total of 32 of these surface water rights are used either for irrigation or stock watering, and 13 are used for domestic, municipal, or other uses. There are no applications for surface water rights within the cumulative drawdown area.

Table 3-17
Summary of Surface Water Rights Within the Cumulative Drawdown Area

Ground Water Basin	Domestic	Irrigation	Mining/ Milling	Municipal	Stock	Other	Total
Surface Water Right with Current *Permit, Certificate*, or *Vested* Status							
Susie Creek Area	0	0	0	0	0	1	**1**
Maggie Creek Area	0	3	0	0	4	0	**7**
Marys Creek Area	0	0	0	4	0	4	**8**
Boulder Flat	1	7	0	0	7	3	**18**[1]
Rock Creek Valley	0	0	0	0	9	0	**9**
Willow Creek Valley	0	0	0	0	2	0	**2**
Total	**1**	**10**	**0**	**4**	**22**	**8**	**45**[1]

[1]Twelve of these surface water rights are primary and secondary storage at the TS Ranch Reservoir associated with mine dewatering rights.

The actual potential for impacts to individual water rights would depend on the site-specific hydrologic conditions that control surface water discharge. For example, as discussed previously under springs and seeps, only those waters that are sustained by discharge from the regional ground water system are likely to be impacted by mine-induced drawdown. Some surface water rights divert only surface water runoff or local perched ground water not dependent on discharge from the regional ground water system. In these cases, impacts to surface water flows from mine-induced drawdown are not anticipated.

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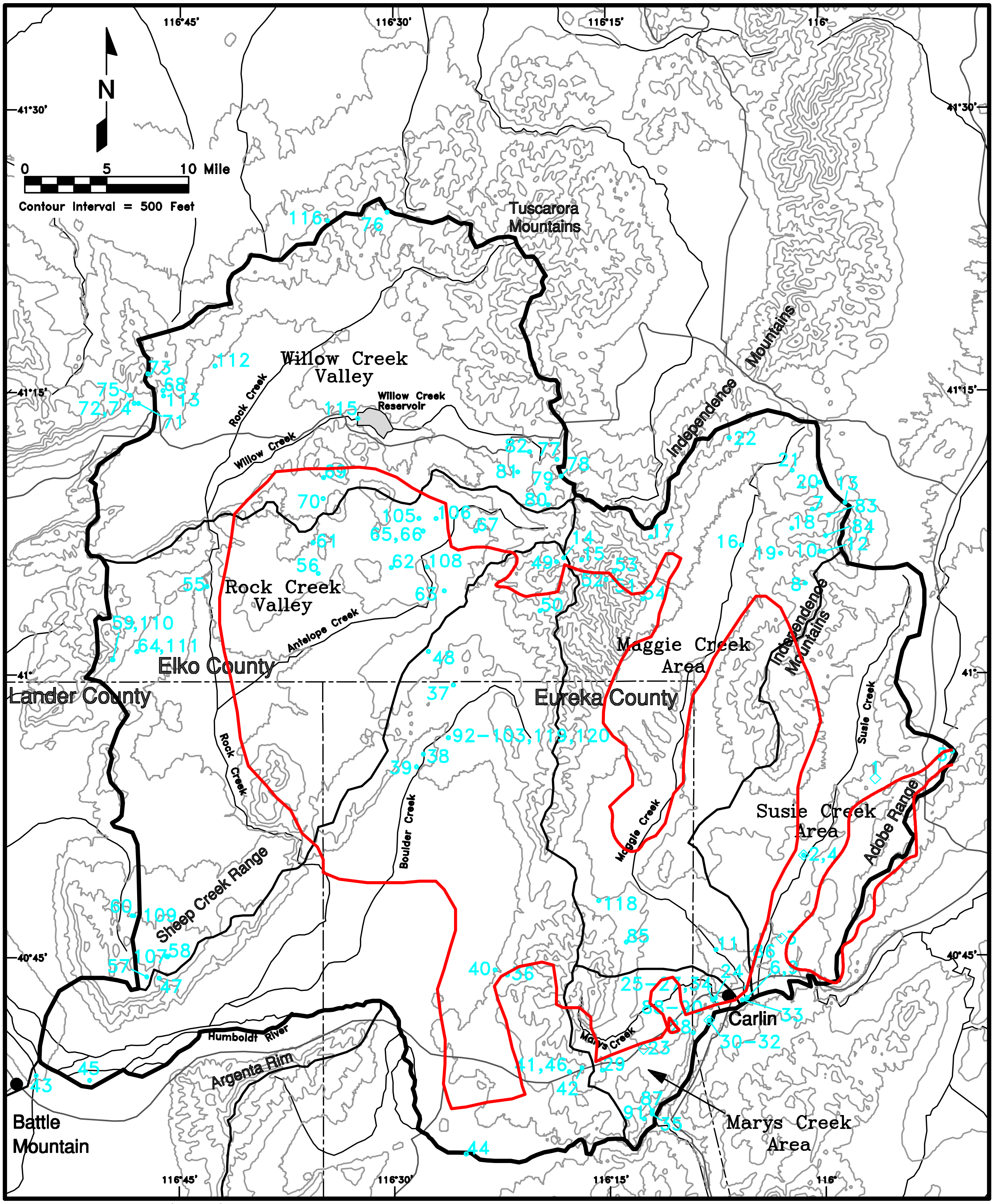


Legend

- Study Area
- Ground Water Basin Boundary
- Predicted Maximum Extent of 10-foot Drawdown
- Stream
- County
- 46 Point of Diversion for Surface Water with Current Permit, Certificate, or Vested Status
- 23 Listed Point of Diversion for Applications for Surface Water Right (Application, Ready for Action, and Ready for Action Protested)

See Table A-2 for details

Figure 3-21

Predicted Maximum Extent of 10-foot Drawdown Relative to Surface Water Rights and Application for Surface Water Rights

3.2.7 Impacts to the Regional Water Balance

As presented in Table 1-1, the combined pumping from the Goldstrike, Gold Quarry, and Leeville mines would result in an estimated total pumped volume of approximately 2,000,000 acre-feet of water. An estimated 800,000 acre-feet (or 40 percent) of the pumped volume would be returned to the ground water system by infiltration activities (e.g., irrigation activities, injection, reservoir seepage); an estimated 570,000 acre-feet (29 percent) would be discharged to the Humboldt River and thereby removed from the hydrologic study area. (Note that the infiltration estimates assume 30 percent of the total volume of water used for crop irrigation infiltrates to ground water.) The remaining 630,000 acre feet (31 percent) of the pumped ground water includes water 1) used for crop irrigation, 2) used at the mine sites for mining and milling and other operations, or 3) lost by evaporation. The collective mine dewatering operations, water management activities, and ground water inflow to pit lakes during the postclosure period would change the general water balance in the hydrologic study area.

Maurer et al. (1996) provided estimates of the ground water flows for the six ground water basins within the hydrographic study area (see Table 3-3). These estimates were used by McDonald Morrissey Associates to develop a conceptual ground water flow system for development of the Barrick regional hydrologic model (MMA 1996a, 1996b, 1997). After model calibration, the model was used to compare the estimated flows with the model-simulated flows into and out of each basin (MMA 1998). This model was later used to evaluate both drawdown and potential changes to the flows for each basin resulting from the cumulative mine dewatering and water management activities (Barrick 1998c, 2000a). These results have not been presented for the Newmont model (HCI 1998b, 1999b); therefore, the Barrick model was used in this evaluation to estimate potential changes in the water balance for the hydrolographic basins resulting from the cumulative mine dewatering and water management activities.

Barrick's numerical model was used to calculate an annual ground water and surface water balance for each of the six hydrographic basins in the hydrologic study area (Barrick 1998c). Annual budgets were calculated from the model output for selected representative mining and postmining periods, including 1996, 2011, 2061, 2111, and post-recovery steady state. The budget tables for these representative time frames are presented in Barrick 1998c. The water balances provide an estimate of the combined effects of mine-induced drawdown and water management activities on the major hydrologic components (such as subsurface inflow and outflow, infiltration, evapotranspiration, and stream discharge) and changes in ground water storage.

To create a basis for comparison, the model was run to simulate conditions that would have occurred in the future assuming that no pumping or infiltration activities occurred at the Goldstrike, Gold Quarry, or proposed Leeville mines. This simulation is referred to as the "null" case and is similar to steady-state conditions except that the model uses seasonal variations in recharge and evapotranspiration to simulate seasonal changes in storage. The results of the null case are listed in Tables 3-18, 3-19, and 3-20 under the column heading "Simulated Conditions Without Mining." For the null case, natural ground water inflow components consist of 1) recharge, 2) ground water inflow from the adjacent hydrographic area, and 3) ground water inflow from infiltration of surface water along streams. Natural ground water outflow components include 1) evapotranspiration, 2) subsurface outflow leaving the hydrographic area, and

Table 3-18
Simulated Annual Ground Water Budget for the Boulder Flat Hydrographic Area at Various Times
(acre-feet)

Budget Components	Simulated Conditions Without Mining	Mining		Postmining		Post-Recovery
		1998	2011	2061	2111	(steady state)
INFLOW						
Direct Recharge	11,200	11,300	11,300	11,200	11,200	11,200
Subsurface Inflow	15,300	23,200	21,000	14,300	14,100	14,800
Stream and River Infiltration						
Humboldt	24,700	25,400	24,700	24,700	24,700	24,700
Other	28,600	35,200	26,300	25,900	25,900	27,200
Infiltration						
Irrigation		31,700	7,700			
Injection Wells						
Reservoirs		13,500				
Ponds		5,000				
Total	**79,800**	**145,300**	**91,000**	**76,100**	**75,900**	**77,900**
OUTFLOW						
Evapotranspiration						
Natural ET	66,200	62,700	70,400	59,700	58,900	62,500
Crop ET		22,200	5,400			
Subsurface Outflow	7,100	7,600	7,400	6,200	6,300	6,900
Stream and River Discharge						
Humboldt	0					
Other	6,900	20,500	4,600	4,100	4,200	5,600
Ground Water Pumpage						
Barrick		100,300	18,100			
Newmont		500	6,800			
Pit Lake						
Seepage				3,500	3,700	2,900
Total	**80,200**	**213,800**	**112,700**	**73,500**	**73,100**	**77,900**
CHANGE IN GROUND WATER STORAGE	**-400**	**-68,500**	**-21,700**	**2,600**	**2,800**	**0**

ET = evapotranspiration.
Source: Barrick 1998c.

Table 3-19
Simulated Annual Ground Water Budget for the Maggie Creek Hydrographic Area at Various Times (acre-feet)

Budget Components	Simulated Conditions Without Mining	Mining		Postmining		Post-Recovery
		1998	2011	2061	2111	(steady state)
INFLOW						
Direct Recharge	13,800	13,800	13,900	13,800	13,800	13,800
Subsurface Inflow	3,500	4,400	7,800	4,400	3,600	3,400
Stream and River Infiltration						
Humboldt						
Other	28,500	29,000	30,000	29,600	29,200	28,500
Infiltration						
Irrigation						
Injection Wells						
Reservoirs						
Ponds						
Total	**45,800**	**47,200**	**51,700**	**47,800**	**46,600**	**45,700**
OUTFLOW						
Evapotranspiration						
Natural ET	12,600	9,300	12,600	12,500	12,500	12,600
Crop ET						
Subsurface Outflow	7,200	12,000	11,300	7,500	7,400	7,300
Stream and River Discharge						
Humboldt	100	100	100	100	100	100
Other	26,200	24,900	23,100	22,700	22,600	24,700
Ground Water Pumpage						
Barrick						
Newmont		25,800	22,200			
Pit Lake						
Seepage				2,200	2,200	1,200
Total	**46,100**	**72,100**	**69,300**	**45,000**	**44,800**	**45,900**
CHANGE IN GROUND WATER STORAGE	**-300**	**-24,900**	**-17,600**	**2,800**	**1,800**	**-200**

ET = evapotranspiration.
Source: Barrick 1998c.

Table 3-20
Simulated Annual Ground Water Budget for the Rock Creek Hydrographic Area at Various Times (in acre-feet)

Budget Components	Simulated Conditions Without Mining	Mining		Postmining		Post-Recovery
		1998	2011	2061	2111	(steady state)
INFLOW						
Direct Recharge	9,800	9,800	9,900	9,800	9,800	9,800
Subsurface Inflow	6,800	7,200	6,000	5,900	6,000	6,700
Stream and River Infiltration						
Humboldt						
Other	9,600	8,800	9,700	9,600	9,500	9,600
Infiltration						
Irrigation						
Injection Wells						
Reservoirs						
Ponds						
Total	**26,200**	**25,800**	**25,600**	**25,300**	**25,300**	**26,100**
OUTFLOW						
Evapotranspiration						
Natural ET	1,000	800	1,000	1,000	1,000	1,000
Crop ET						
Subsurface Outflow	15,600	18,900	17,500	14,600	14,300	15,100
Stream and River Discharge						
Humboldt						
Other	10,600	13,200	10,500	10,100	10,000	10,100
Ground Water Pumpage						
Barrick						
Newmont						
Pit Lake						
Seepage						
Total	**27,200**	**32,900**	**29,000**	**25,700**	**25,300**	**26,200**
CHANGE IN GROUND WATER STORAGE	**-1,000**	**-7,100**	**-3,400**	**-400**	**0**	**-100**

ET = evapotranspiration.

Source: Barrick 1998c.

3) ground water discharged to streams. For the null case, the hydrologic system is nearly in balance, i.e., total inflow is approximately equal to total outflow.

For the other modeled scenarios, the simulated annual water budgets account for water extracted from pumping, infiltration and seepage, evapotranspiration changes, and mine discharge activities. Infiltration and seepage are significant contributors to the overall annual inflow to the system and offset a portion of the ground water extracted from the mine dewatering systems. Outflows from the basin resulting from mine discharges to streams and rivers and increased evapotranspiration from crop irrigation also are accounted for.

The simulated water budgets predict that there would be no changes in the Willow Creek Hydrographic Area and only minor changes in the Marys Creek and Susie Creek Hydrographic Areas (Barrick 1998c). The model simulations, as summarized in Tables 3-18, 3-19, and 3-20, predict that the combined mine-induced drawdown and water management activities would result in a noticeable change in the water balance, particularly in the Boulder Flat and Maggie Creek Hydrographic Areas, and to a lesser extent in the Rock Creek Hydrographic Area.

For the Boulder Flat Hydrographic Area (Table 3-18), the simulated ground water balance suggests that during mining the amount of subsurface flow from adjacent basins into the Boulder Flat Hydrographic Area has nearly doubled and would continue to be substantially higher than premine conditions throughout the mine life but would return to near premine conditions in the postmining period. The simulated water balances also suggest that there already has been a substantial increase in infiltration from streams, and infiltration resulting from reservoir seepage, pond infiltration, irrigation, and injection wells. However, all of these increases in infiltration are predicted to be short-term. In later stages of the Goldstrike Mine life, as represented by the water balance for 2011, infiltration is predicted to be similar to premine conditions with the exception of additional infiltration from irrigation activities. Ground water outflow would increase substantially during mining as a result of the combined effects of pumping and increased evapotranspiration resulting from ground water mounding and crop irrigation in Boulder Valley. In the postmining period, the amount of evapotranspiration is simulated to be less than premine conditions. This predicted long-term postmining reduction in evapotranspiration reflects the fact that as the water table is lowered, there would be less ground water loss through evapotranspiration processes. In the postmining period, some ground water outflow from the system would occur as seepage for pit lake filling, and at steady state, to replace water lost from pit lake evaporation. During mining, ground water outflow is greater than inflow, resulting in reduction in ground water stored in aquifers in the hydrographic area. However, in the postmining periods, there is predicted to be approximately 4 percent more inflow than outflow, resulting in a gradual increase (and partial recovery) of ground water stored in the basin.

The simulated water balances for the Maggie Creek Hydrographic Area (Table 3-19) indicate that mine dewatering is anticipated to increase ground water outflow from the Maggie Creek Hydrographic Area during mining, mainly to the Boulder Flat Hydrographic Area. During mining, pumping results in a reduction in ground water in storage. However, reductions in storage are not anticipated within the 50-to 100-year postmining period.

The Rock Creek Hydrographic Area simulated water balances (Table 3-20) indicate both subsurface inflow and outflow would increase up to approximately 70 percent compared to estimated premine conditions. Increased subsurface inflows are largely the result of mounding expanding into this area from mine infiltration activities in the adjacent Boulder Flat Hydrographic Area. Increased subsurface outflow indicates that drawdown from the adjacent Boulder Flat Hydrographic Area results in additional movement of ground water into the Boulder Flat Hydrographic Area. Drawdown is anticipated to result in a reduction of ground water stored in this hydrographic area during mining and into the postmining period. However, by approximately 2061 the water balance estimates indicate that the basin would be nearly at a state of renewed equilibrium.

3.3 Impacts to the Humboldt River

3.3.1 Impacts to River Flows from Combined Mine Discharges

3.3.1.1 Background

A Humboldt River regional study area was defined to assess potential cumulative impacts from combined mine discharges. This study area extends along the river from Carlin, Nevada, to the Humboldt Sink, as shown in Figure 1-1. This analysis examines the potential cumulative impacts to the Humboldt River from current and projected future mine discharges. Seven mines in the Humboldt River Basin are involved in dewatering activities for purposes of accessing ore bodies. These mines include Cortez Pipeline (Cortez Gold), Twin Creeks (Newmont), McCoy/Cove (Echo Bay), Goldstrike, Gold Quarry, Leeville (proposed), and Lone Tree. Evaluation of dewatering and mine water disposal plans, NEPA documentation, and other documents indicates that the first three (Cortez Pipeline, Twin Creeks, and McCoy/Cove) have little or no effect on Humboldt River flows (BLM 1996c; HCI 1997a). As a result, this analysis addresses discharge from the Lone Tree, Gold Quarry, and Goldstrike mines, and the proposed Leeville Mine.

Newmont's Lone Tree Mine began discharging treated water to the Humboldt River via the Iron Point Relief Canal near Valmy, Nevada, in May 1992. In April 1994, Newmont's Gold Quarry Mine began discharging to Maggie Creek near Carlin, Nevada. Similarly, Barrick discharged treated water to the Humboldt River from the Goldstrike Mine dewatering operations from September 1997 to February 1999. Goldstrike Mine water also has been stored in the TS Ranch Reservoir, infiltrated, injected to ground water recharge, or consumed by irrigation. If approved, the proposed Leeville Mine is anticipated to irrigate and infiltrate water, and as necessary, discharge to the Humboldt River through the existing Goldstrike Mine water conveyance system beginning in 2000. Additional details regarding pumping and discharge are presented in Chapter 1.0 and in Tables 1-1 and 1-2. The following sections describe the analyses and potential impacts related to flow regimes and water quality in the Humboldt River.

The most upstream point on the Humboldt River mainstem that receives mine dewatering discharge is the confluence of the river with Maggie Creek near Carlin in Elko County, as shown in Figure 1-1. At this location, dewatering discharges from the Gold Quarry Mine enter the river. The upstream boundary of the cumulative impact assessment is the location where these flows combine with the Goldstrike Mine dewatering discharges at the Goldstrike Mine outfall near the western Eureka County line (see Figure 1-1).

In this analysis, the most downstream mine discharge is the Lone Tree outfall at Herrin Slough, located between the USGS stream gages at Battle Mountain and Comus (see Figure 1-1). Given the availability of data and the location of discharges into the Humboldt River, the impact analysis upstream of the Comus gage is more quantitative, and the impact assessment of the river below Comus is more qualitative in nature. As described in Section 3.1.3, substantial flow losses occur in the river downstream of Battle Mountain and Comus.

Figure 3-22 shows the current estimated discharges (historical and projected) for each mine, as well as the estimated cumulative mine discharge for the period 1992 through 2011. These discharges are based on descriptions of mining operations presented in Chapter 1.0. The amount of water pumped for dewatering is not equal to the amount of water discharged to the river. A substantial amount of the water is consumed in mining operations, irrigation, infiltration, injection, and other uses. The magnitude of these uses varies seasonally. The remaining flows are treated, as necessary, to meet Nevada discharge standards and released to the river.

As shown in Figure 3-22, discharges to the Humboldt River have increased over time since the early 1990s to a maximum of approximately 100,000 gpm. Rates of discharge to the river may increase or decrease in the future as the mines continue their water management programs. The future discharges shown in Figure 3-22 are based on the most recent projections from individual mining operations.

3.3.1.2 Impacts to Date to Humboldt River Flows

Effects to date from mining discharges to the Humboldt River were examined by reviewing precipitation and stream gage data. The data review compared flow data for the years 1946-1990 (pre-discharge) to the flows in the years since mine discharges have occurred (1991-1998). Available precipitation data, including both snow and total annual precipitation, also were reviewed during this comparison in an effort to put the streamflow data in the context of general climatic conditions in the Humboldt River Basin. This review used a simple comparison and rating system that examined several precipitation stations with meaningful data histories in the upper part of the river basin (above Palisade) and several in the lower part of the river basin (below Palisade). No other major influences on streamflows (as described in Sections 3.1.1.2 and 3.1.3.1) were included in this semi-quantitative review. The results of the data review are shown in Appendix C, Tables C-9 and C-10.

In part, the data examination demonstrates the differences in precipitation and flow regimes from location to location within the basin. In Table C-9 for example, point precipitation data for 1992 at Battle Mountain was approximately 37 percent above normal at that particular location. However, on an area-wide basis using several additional stations, both the upper and lower subbasins had below normal rainfall. In 1991 and 1994, the upper and lower Humboldt River sub-basins differed in precipitation but did not differ significantly in relative streamflows. As northern Nevada generally emerged from several years of drought in the late 1980s and early 1990s, a general increase in streamflows occurred throughout the Humboldt River basin (Table C-10). The years 1995 through 1998 were generally characterized by high precipitation accumulation and correspondingly higher streamflows. Substantially greater increases in streamflows can be seen in 1995

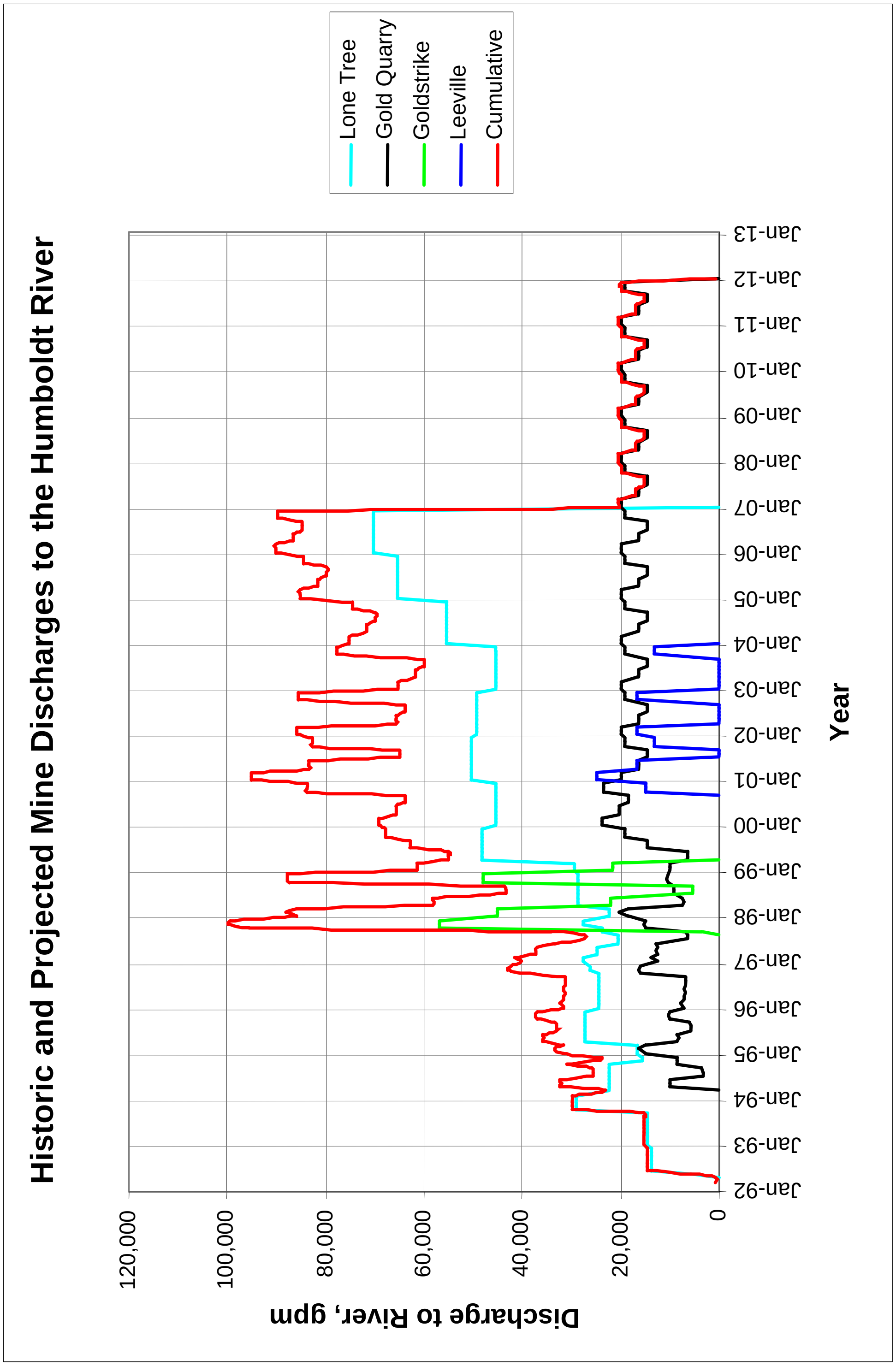


Figure 3-22

Mining Discharges to the Humboldt River

through 1998 data for Battle Mountain and other downstream gages in comparison to the upstream Carlin and Elko data.

Goldstrike and Gold Quarry mine discharges combine in the Humboldt River upstream of the Battle Mountain gage. Mine discharges probably had some effect on the greater annual increases in streamflow at that location and farther downstream during the 1995-1998 period (where higher annual flows are evident in the record). However, incremental effects of mine discharges on the river flows are not clearly expressed in the streamflow data. In some months, decreases in flow from upstream to downstream are evident. Appendix C, Table C-11 presents the flow variations during the recent higher flow years of 1995 through 1998.

The 1997 data indicate that streamflow increased substantially in the winter and spring prior to Barrick's historical discharges (starting in September 1997) and when Newmont was discharging a monthly average of 30 cfs or less at Gold Quarry. This relatively small mine discharge cannot account for the differences in flow increases between Carlin and Battle Mountain. For example, the mean monthly flow for January 1997 at Carlin (above the Gold Quarry discharge) is 394 cfs. The 1946-1990 January average is 148 cfs. In contrast to the Carlin data, the mean monthly flow for January 1997 at Battle Mountain is 1,123 cfs, and the 1946-1990 January average is 178 cfs. Similar conditions can be observed in other monthly data for the higher flow years between Carlin and Battle Mountain. It also should be noted that January 1997 flows at Battle Mountain are approximately 80 percent in excess of the maximum 1946-1990 flow for that month, and mine discharges only represent 3 percent of the flow. For other months, combined river and mine discharges recorded at the Battle Mountain gage are all within the historical monthly range of flows (Appendix C, Table C-8).

During lower flow periods, generally August through October, data suggest that a larger portion of the flow increases may be composed of mine discharges. In general, many of the differences in precipitation effects (including snowmelt runoff) between subbasins are dampened out during this period in comparison to the rest of the year. The differences in flows between Carlin and Battle Mountain during these months are more similar to the magnitudes of the mine discharges. However, irrigation practices and other factors also affect these data.

The streamflow data at the Comus gage is influenced by the Lone Tree, Goldstrike, and Gold Quarry mine discharges. Between Battle Mountain and Comus, flow changes in the recent high-flow years generally reflect conditions similar to those upstream. More use (loss) of the mine discharges can be seen in this reach. In addition, there are considerably more months where there are substantial flow decreases between stations, even with the contributions from mine discharges. For all months, the combined river and mine discharges as recorded at the Comus gage are within the historical monthly range of flows (Appendix C, Table C-8).

It should be noted, per the calculations and footnote on Table C-11 of Appendix C, that it is quite possible for part or all of the mine discharges to be withdrawn from the river and consumed by other users of Humboldt River water. This may have occurred as an impact-to-date as reflected in the table entries where substantial flow losses are shown from upstream to downstream gages. In such cases, substantial beneficial impacts to water users may have resulted from the mine discharges.

At times, mine discharges to date have contributed to flow increases in the Humboldt River. However, this data review indicates that various conditions and water uses contribute to Humboldt River streamflow data, including differences in the size of the drainages being gaged, precipitation accumulation and snowmelt in different parts of the basin, alluvial aquifer gains and losses, agricultural diversions and returns, evapotranspiration, as well as mine discharges. As a result, it is not possible to quantitatively distinguish the incremental increase in flow attributable to the combined mine discharges by a simple comparison of streamflow records.

Using the Battle Mountain gage as the nearest downstream reference for combined dewatering discharges, in the winter and spring of 1997 river flows increased substantially above their historical values. At that time Barrick was not discharging, and Gold Quarry was discharging a monthly average of 30 cfs or less. Thus, the dramatic flow increases from Carlin to Battle Mountain in early 1997 were probably due to regional weather phenomena (such as rain on snow), similar to what occurred in other Nevada river basins at the time. The mine discharges were too small to account for the flow increases along the river.

3.3.1.3 Projected Future Maximum Impacts to Humboldt River Flows

In order to assess future potential impacts of mine discharges to the Humboldt River, dewatering discharge scenarios were simulated by computer modeling (HCI 1997a; RTi 1998). The discharge scenario independently modeled by HCI (1997a) includes the effects of ground water drawdown and mounding on long-term postmining river flows (see Section 3.3.2 and Figures C-3 through C-6 in Appendix C.). An independently modeled scenario by RTi (1998) includes the effects of irrigation withdrawals and returns using the StateMod model (Colorado Division of Water Resources 1996). All scenarios used USGS streamflow data as a basis of comparison for an average flow year, high-flow year, and low-flow year.

The StateMod river simulation approach was used to analyze the maximum combined discharge scenario (RTi 1998). In this approach, changes to river flows were estimated by superimposing the monthly mine flows from the maximum predicted cumulative year of dewatering discharge (Table 3-21) onto the river flows and running the Statemod computer model. These simulations were conducted for a historic average year, a historic low-flow year, and a historic high-flow year, based on streamflow records and data for the period 1946 through 1990. The simulations accounted for seasonal irrigation diversions and returns assuming that future irrigation diversion rates remained similar to those of the present day (NRCS 1997).

For RTi's quantitative evaluation of the Humboldt River upstream of Comus, the average return flow percentage was assumed to be 30 percent. The impact analysis presented for the project is very sensitive to the return flow percentage. Since this number is not known to have been determined explicitly either through experimental or analytical means for the Boulder Flat region or other regions included within the Carlin to Comus reach of the Humboldt River, the 30 percent return flow percentage used in the subsequent analysis represents a reasonable approximation based on agency estimates (NRCS 1997; Testolin 1997).

Table 3-21
Projected Maximum Cumulative Mine Discharges to the Humboldt River
(cfs, rounded)

Mine	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (acre-feet, rounded)
Goldstrike	33	33	33	0	0	0	0	0	0	32	32	32	11,800
Leeville	35	35	35	0	0	0	0	0	0	35	35	35	12,700
Gold Quarry	35	25	11	14	28	33	22	36	25	44	53	51	22,800
Lone Tree	182	144	149	172	133	135	162	146	150	206	179	149	115,300
TOTAL	**285**	**237**	**228**	**186**	**161**	**168**	**184**	**182**	**175**	**317**	**299**	**267**	**162,600**

Source: RTi 1998.

<u>Average Seasonal Hydrograph Simulation Results</u>

This section describes the effects of the projected cumulative discharges to flows in the Humboldt River. As analyzed by RTi (1998), the results presented in Figures 3-23 and 3-24 illustrate the combined flows in the river that are predicted at Battle Mountain and Comus when the maximum cumulative mine discharges (Table 3-21) are simulated along with an historical average river flow. The peak flow months of April, May, and June show little relative change at the Battle Mountain gage. The peak flow month of June shows an increase in average flow of approximately 2 percent.

At the Comus gage, all months except April, May, and June show at least a 20 percent flow increase (and often much larger) in the simulations. The month with the largest relative change in flow is October, followed by September, and November. Peak flow months of April, May, and June show lesser increases in average flow at the Comus gage. The peak flow month of June represents an increase in average flow of approximately 9 percent, compared to the baseline average. Changes at Imlay are expected to be similar to the pattern at Comus, but on a smaller scale due to flow losses between the stations.

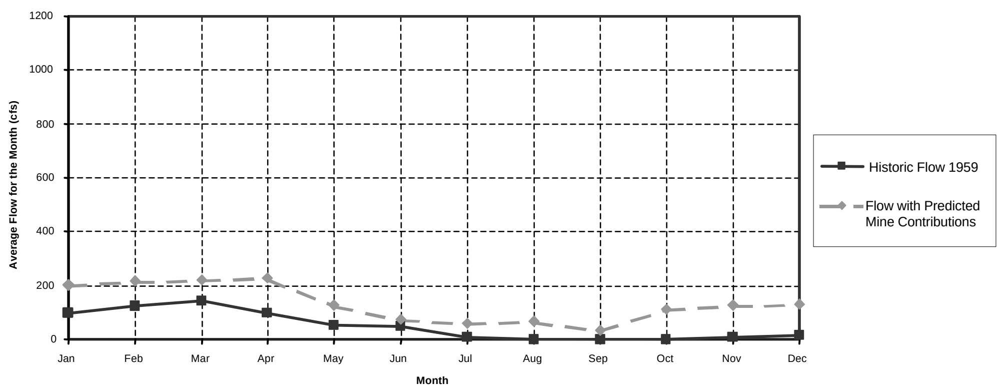
The maximum combined discharge scenario also was examined in a separate study by HCI (1997a). The results of HCI's simulations are presented in Appendix C. The HCI simulations project similar magnitudes of potential flow increases as described for the RTi model.

<u>Low Water Year Simulation Results</u>

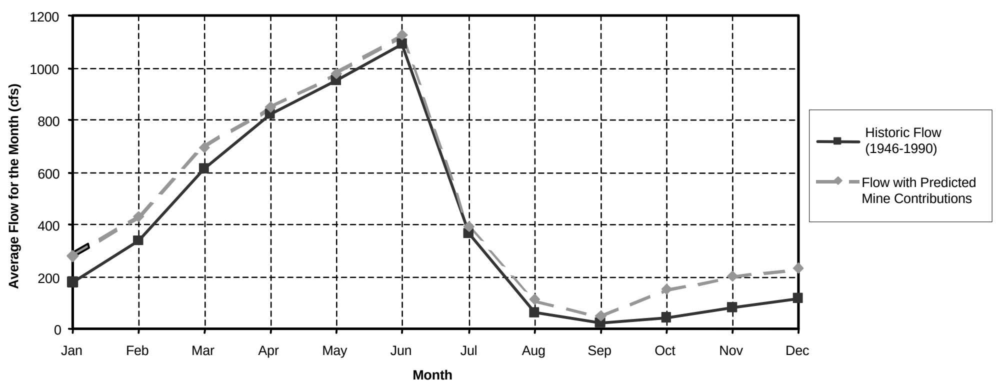
As analyzed by RTi (1998), the results presented in Figures 3-23 and 3-24 illustrate the combined flows in the river that are predicted at Battle Mountain and Comus when the maximum cumulative mine discharges (Table 3-21) are simulated along with a historic low-flow year on the river (represented by 1959 historic data). The simulations show that there is a large relative change to the average monthly flows for the late summer and fall months at both the Battle Mountain and Comus gages under the maximum discharge scenario. The most notable change to the low-flow hydrograph is the shift of water to the low-flow period of October through February.

With the maximum mine discharges, the largest relative changes at the Battle Mountain gage occur in the months of August, September, and October in the RTi analysis. With the maximum mine discharges, the

Projected Changes to Low Water Year (1959), Flows at Battle Mountain



Projected Changes to Average Flows at Battle Mountain



Projected Changes to High Water Year (1984), Flows at Battle Mountain

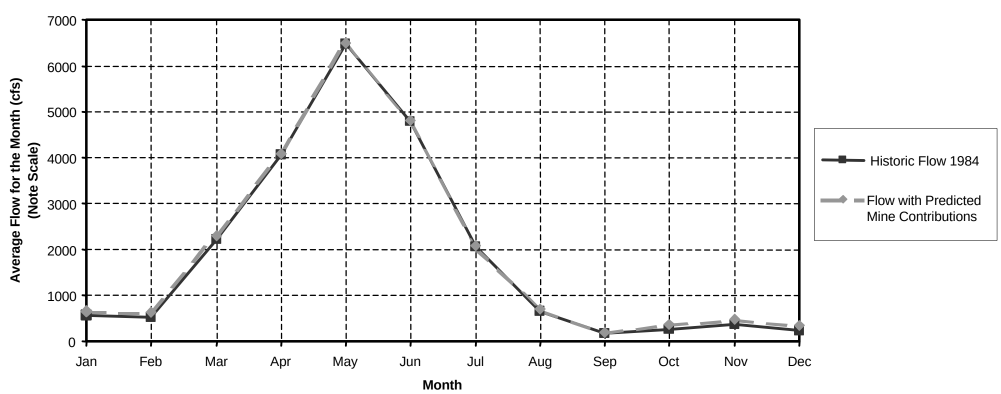
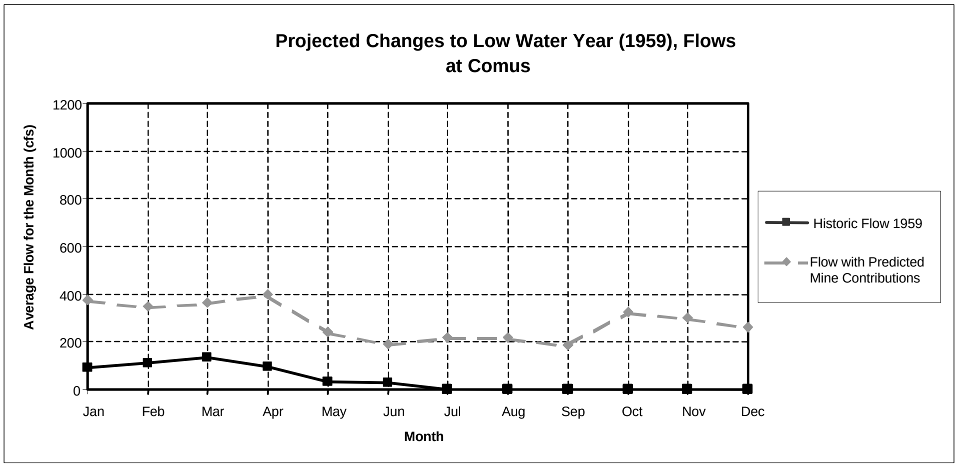
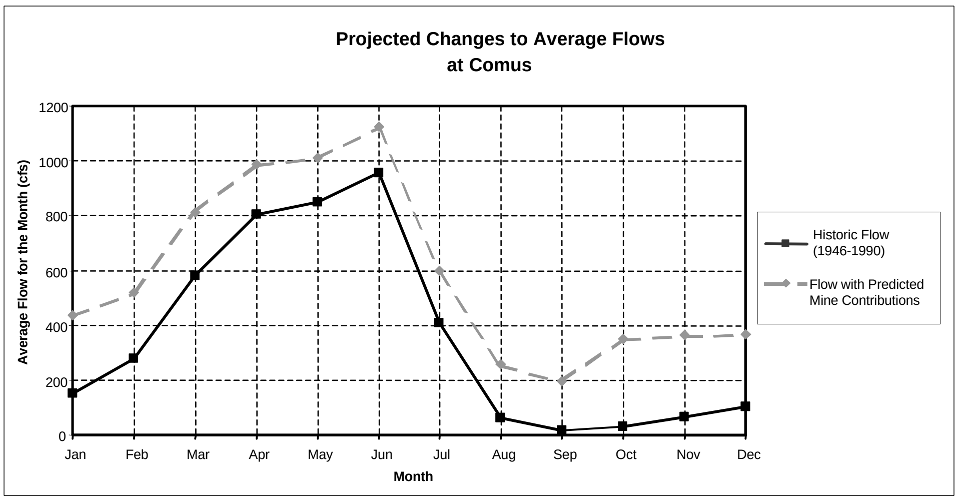


Figure 3-23

Projected Changes to Flows at Battle Mountain





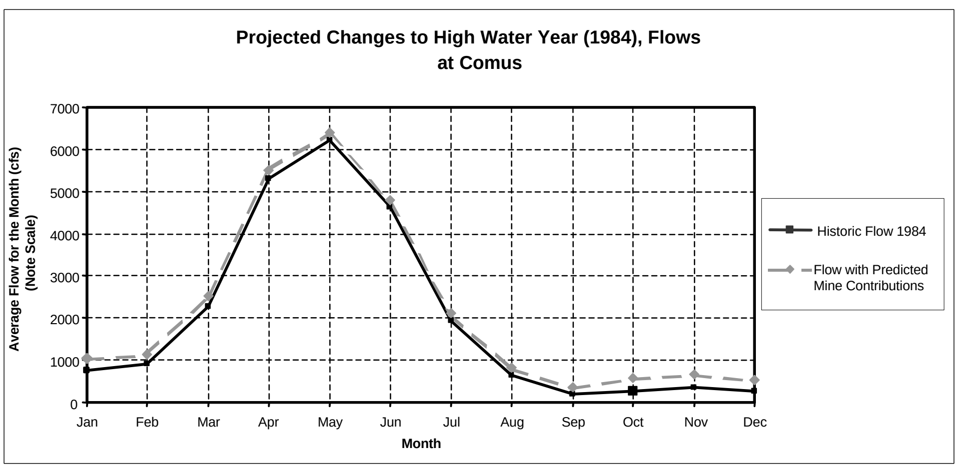


Figure 3-24

Projected Changes to Flows at Comus

largest relative changes at the Comus gage occur from August through December in both modeling approaches. Flow increases of several thousand percent resulted, since on an average basis the river was almost dry in those months. Flow changes at Imlay are expected to be similar to the pattern at Comus, but on a smaller scale due to flow losses between the stations.

High Water Year Simulation Results

As analyzed by RTi (1998), the results presented in Figures 3-23 and 3-24 illustrate the combined flows in the river that are predicted at Battle Mountain and Comus when the maximum cumulative mine discharges (Table 3-21) are simulated along with an historical high-flow year on the river (represented by 1984 historical data).

The largest relative change in flows at the Battle Mountain gage occurs from October through December, showing an increase in the average flows of approximately 30 to 50 percent for those 3 months. The largest relative change in flows at the Comus gage occurs from September through December, showing an increase in the average flows of approximately 70 to 130 percent in those months. Flow changes at Imlay are expected to be similar to the pattern at Comus, but on a smaller scale due to flow losses between the stations.

3.3.2 Projected Baseflow Decreases in the Humboldt River from Dewatering Effects

HCI (1997a) investigated the effects of dewatering on long-term flows in the Humboldt River. Substantial parts of these investigations focused on potential decreases in flows after dewatering discharges cease. As described in Section 3.2, cumulative dewatering activities are anticipated to create additional ground water drawdown in parts of the study area. The HCI modeling assesses cumulative impacts, and it indicates that cumulative drawdown would affect the amount of ground water that contributes to flow in the river throughout the year.

The portion of river flow that is derived from ground water contributions is called baseflow, which is fairly consistent throughout the year. Baseflow rates usually vary slowly in response to wet or dry years. Observed flow in a stream during the early autumn (e.g., October) is frequently used as a benchmark for the baseflow portion of an annual stream hydrograph. (Examples of annual stream hydrographs are shown in Sections 3.1.3.2 and 3.3.1.3). Baseflow is not necessarily synonymous with low flow, since low flows may be affected by manmade withdrawals, returns, and seasonal evapotranspiration demands. The HCI studies predict that when dewatering discharges cease (planned at the end of 2011), average river flows would become slightly lower than the historic averages. This effect is predicted for streamflow gages at Palisade, Argenta, Battle Mountain, Comus, and Imlay, and would probably occur at Dunphy as well (see Figure 1-1). On an annual basis, the initial decreases would be approximately 1 percent of the average yearly volume at these gaging locations. In the years 2016 to 2019, the flows would be reduced by a maximum of 2 to 3 percent of the average yearly volume at these gaging stations. Approximately 97 to 98 percent of the historic average annual flow would still occur in the river during this period. The predicted year of maximum decrease varies with location along the river, but is predicted to be approximately 2019 (HCI 1997a).

Following these temporary maximum reductions, flows are predicted to gradually return to approximately 99 percent of their historic average annual volumes by approximately the year 2095.

From an average monthly flow standpoint, HCI predictions indicate that flow reductions may be more significant during the low-flow months on the Humboldt River. For selected gages along the river, Table 3-22 shows the predicted maximum decreases during the low-flow season relative to the historic monthly average flows as determined by HCI.

Table 3-22
Projected Maximum Decreases in Humboldt River Discharge
(cfs, rounded)

Streamgage Location	July	August	September	October	November
Argenta					
Average Historical Flow	332	38	13	22	58
Maximum Predicted Decrease	-8	-8	-8	-8	-8
Battle Mountain					
Average Historical Flow	325	43	14	26	64
Maximum Predicted Decrease	-8	-8	-8	-8	-8
Comus					
Average Historical Flow	404	70	18	27	56
Maximum Predicted Decrease	-8	-8	-8	-8	-8

Source: HCI 1997a.

Ultimately, the baseflows would recover to approximate the historic values described above. However, Table 3-23 indicates that during the low-flow season, predicted baseflow reductions would comprise a larger portion of the historic monthly flows. In any particular year, low flows on the river would differ from these average conditions, since the river historically has gone dry from other causes. Effects from mining drawdown would add to the existing flow withdrawals along the river, potentially affecting low-flow conditions. If they occurred, the impacts would consist of decreases in monthly water volumes, shallower depths of flow, and somewhat narrower widths of flow. Based on the most recent available USGS rating curves and the discharge estimates from HCI, the potential changes in flow depths for selected months at Battle Mountain and Comus are shown in Table 3-23.

In general, the estimated changes in depth are slight and may not affect the ability of current irrigation intakes or outfalls to divert or return water. From a supply standpoint, however, it has been noted that the diversion flows allowed by the Humboldt River decrees are already so low as to limit the dispersion of water over the surfaces of fields and pastures (Hennen 1964). In spite of water rights, this limits the amount of land that can be irrigated in practice and creates the need for remedial water supply measures on the part of the State Engineer. Decreasing flows, particularly during the latter part of the irrigation season, would exacerbate this situation.

Table 3-23
Projected Maximum Decreases in Humboldt River Stages (feet)

Streamgage Location	July	August	September	October	November
Battle Mountain					
Stage at Average Historical Flow	4.63	3.10	2.80	2.94	3.28
Stage at Maximum Predicted Decrease	4.61	3.03	2.67	2.85	3.21
Change	-0.02	-0.07	-0.13	-0.09	-0.07
Comus					
Stage at Average Historical Flow	4.62	2.75	2.14	2.28	2.61
Stage at Maximum Predicted Decrease	4.59	2.67	2.00	2.16	2.53
Change	-0.03	-0.08	-0.14	-0.12	-0.08

Source: HCI 1997a; USGS 1998b.

In response to the potential effects of decreased river flows, Newmont has committed to augmenting low flows in the river using senior water rights that the company owns or controls (BLM 1993d). After cessation of the mine dewatering discharges, Newmont will undertake a program to mitigate potential water losses to irrigation water rights holders in the middle and lower Humboldt River subbasins. Prior to each irrigation season, Newmont will determine the acre-feet of water that might be lost during that season, based on the projected impacts to Humboldt River baseflows for that year. Newmont will work closely with the river Water Master to administer a like amount of its senior rights as if they were the most junior rights in the subbasin for that irrigation season. Additional details of this program would be determined on an as-needed basis with appropriate state authorities.

3.3.3 Impacts to Flooding and Flow Geometry from Mine Discharges

As discussed in Section 3.1.1, additional mine discharges would increase Humboldt River flows. Generally, the high-flow months, such as May and June, would not be affected by the additional discharge. Relative to the natural river flows in those months, the increases are small and would have no substantial impact on the flow regime of the Humboldt River during the average peak flow months.

Comparably larger increases relative to the natural flows would occur in the low-flow fall and winter months. The discharges would increase the flow depths in the river and would add to the areal extent (topwidth) of the river in low-flow months. The flow geometry increases would vary according to the cross-sectional geometry of the channel. Wider sections would generally undergo less depth increase and more width increase; narrower sections would experience the opposite. It is anticipated that greater depths and flow extent would generally reduce the potential for isolated pools or branches to form in the river during low-flow periods. Changes in flow geometry from the effects of discharges to date are probably similar to (or less than) to the projected changes described below.

Based on modeling results, a generalized analysis of the mine discharge effects on flow depth and width was conducted using USGS flow measurement data and stage-discharge rating curves. Table 3-24 shows the anticipated changes in river stage from the projected maximum mine discharges. As shown in the table, small changes are anticipated during the high-flow month of June, but more substantial changes are expected during the low-flow month of October.

Table 3-24
Potential Changes in River Stages from Projected Maximum Mine Discharges

USGS Streamgage	Month	Mean Observed Discharge 1946-1990 (cfs)	Observed River Stage 1992-93 Rating (feet)	Mean Simulated Discharge (cfs)	Simulated River Stage 1992-93 Rating (feet)	Simulated Change in Stage (feet)
Battle Mtn.	June	1,108	6.58	1,127	6.62	0.04
	October	42	3.40	152	4.09	0.69
Comus	June	970	6.85	1,125	7.31	0.46
	October	32	2.50	351	4.50	2.0

Source: USGS 1998b; RTi 1998.

These increased flows generally would not create additional flooding along the river upstream of Rye Patch Reservoir. During the highest peak flows (such as may occur during a week in spring in some years), or along constricted reaches of the river during a longer period of relatively high flows (such as may occur during June in most years), limited additional flooding may occur where a change in depth of 1 foot or less would allow the river to escape its banks. The additional inundated area would likely be limited to the immediate vicinity of the river and would generally involve lower elevation hayfields and meadows. The potential for additional flooding downstream of Rye Patch Reservoir is complicated by seasonal streamflow forecasting and its effects on reservoir operations and the regional agricultural infrastructure, as discussed below.

Using a discharge versus river width curve based on USGS information, the changes in low-flow geometry were also examined. Average October flows at Comus are 32 cfs for the period 1946 through 1996. This translates to a flow surface width of approximately 45 feet. Projected October average flow under conditions of maximum combined mine discharges is 351 cfs. For these conditions, using the same slope, roughness, and discharge - width curve, the flow width is anticipated to be approximately 80 feet. The calculated change in width is 35 feet. For comparative purposes, this analysis shows that the increases in flow geometry would be relatively larger during low flows than in the peak months.

During low-flow periods (August through February), flooding outside the streambanks is extremely unlikely. Additional mine discharges would not change that condition. The additional discharges would increase the extent of water within the channel banks during the low-flow season and would potentially provide connections between reaches or backwaters that would otherwise be isolated from one another at low-flow stages.

3.3.4 Impacts to Channel Characteristics and Controls

Effects related to stream erosion, sedimentation, and channel geometry from the cumulative discharges are likely to be small. The Humboldt River channel naturally undergoes large-scale erosion, sedimentation, and position shifts below the point where mine discharges are combined at the Barrick outfall. The wide variation in sediment discharge for a given water flow was previously described in Section 3.1.3.2. Qualitatively, the effects of mine discharges are expected to be less than those associated with other man-made causes, such as grazing and other land uses, or natural processes.

Channel impacts to date from recent historical mine discharges of up to approximately 100,000 gpm (222 cfs) have not been documented. However, the release of over 200 cfs of relatively clear (sediment-free) water for approximately 3 months during the low-flow time of year has likely induced additional deepening and possibly widening of the low-flow section of the river channel. Similar impacts would likely result from future discharges.

Cumulative mine discharges would intensify existing channel instability in the reach extending approximately 3 miles upstream and downstream from the Barrick outfall, which is the most upstream location where mine dewatering discharges would combine to create the potential for cumulative flow effects. In slow-flowing streams, channel disturbances can cause adjustments both upstream and downstream of the disturbance. For this reason, upstream effects may occur because of overall adjustments in the channel system throughout the locale. Additionally, existing instability along the river near the Comus gage and immediately upstream would be exacerbated by the cumulative mine discharges. Low-flow channel expansion (deepening and/or widening) is likely to be the most noticeable effect, since low flows would be most affected by the cumulative mine discharges.

These channel effects would probably be counteracted by subsequent spring runoff. Average annual peak flows in the river are approximately 1,100 cfs, and the bankfull flow (recurrence interval of 2.33 years) is estimated to be approximately 1,500 cfs in the river reach between Dunphy and Argenta. Over time, these peak flows would have a greater influence on overall channel morphology and sedimentation than the smaller mining discharges. As discussed previously, the relative increases in mean annual peak discharges from mine dewatering are expected to be small upstream of Comus. Sediment deposition that may occur during the low-flow season would likely be entrained in the higher spring runoff flows. At Comus and downstream, anticipated flow increases during the maximum annual discharge are higher relative to the average monthly flows throughout the year. It is possible that impacts from bed and bank erosion may occur in these downstream reaches during the larger combined discharges anticipated around 2006.

It is remotely possible that irrigation diversion structures or bridges immediately upstream of the Comus gage and in the Dunphy-Argenta area may require additional inspection and maintenance as a result of increased flows throughout the year (at Comus), or from possible changes in riverbed gradient and bank position. It should be noted that these river reaches have shifted their positions historically, due to a combination of natural and manmade causes that were in effect before mine dewatering occurred (see Section 3.1.3.3 and "River Channel Geometry" in Section 3.1.3.2). The effects of dewatering discharges on flow rates and channel geometry could act in combination with these existing factors to create additional risk from scour and degradation or channel migration at structures where these processes are already ongoing.

If changes in river geometry were substantial enough to cause failure or bypass of the existing river control structures, widespread channel migration could occur along several miles of the river as it attempted to resume its former meandering course. If this were to occur, increased erosion and sedimentation impacts would occur within the current channel and to lands adjacent to the river. Mine dewatering discharges would play a minor role in such circumstances; other land uses, construction activities, and river management practices have had more effect on river system behavior and risk to structures in the floodplain.

3.3.5 Impacts to Rye Patch Reservoir Operations and Irrigation Operations Downstream

Rye Patch Dam and Reservoir are part of the Humboldt Project, which was authorized by Congress to provide irrigation water to approximately 40,000 acres of agricultural land in the Lovelock Valley (Bureau of Reclamation 1995). Construction of Rye Patch Dam was completed in 1936, and in 1941 the operation and maintenance of all Humboldt Project facilities, including the dam, reservoir, conveyances, and other facilities, were transferred by the Bureau of Reclamation to the Pershing County Water Conservation District. The location of Rye Patch Reservoir and the Lovelock area are shown in Figure 1-1.

The greatest potential for impacts to Rye Patch Reservoir and irrigation district from mine water discharges occurs in high water years. In normal and dry years, a substantial positive impact is derived from the benefit of additional flows (Hodges 1998). Normally, additional water can be stored in the reservoir and distributed among the adjudicated rights. An additional 100 to 200 cfs in the river at Comus is the equivalent of approximately 6,000 to 12,000 acre-feet per month, of which some portion would reach the reservoir and downstream irrigators.

Negative impacts could result in high-flow years from additional flows exceeding the reservoir storage limitations and conveyance capacities of the canals and gates. Releases from Rye Patch Reservoir above 1,500 cfs create damage to the irrigation infrastructure and cause flooding of agricultural fields (Hodges 1998). When high flows are not accurately predicted on a seasonal basis, mining discharges could exacerbate the problem of operating Rye Patch Reservoir to preserve emergency storage and minimize flooding and structural damages downstream.

It is important to recognize that predicting surface water supplies from year to year is a difficult task, and a number of natural and man-made variables influence seasonal water storage and availability in the region. Whether additional mine water provides beneficial or adverse impacts depends on complex interactions between the natural variability and the responses of water managers. For this reason, it is not possible to predict the occurrence of potential impacts to irrigation district features strictly from mining discharges. Mining discharges can, however, combine with unforeseen natural runoff phenomena to produce higher risk from flooding, including potential damages to reservoir infrastructures or flooding to low-lying irrigated lands downstream of Rye Patch Reservoir. After mining ceases, the potential for the mining discharges to affect storage at Rye Patch Reservoir also will cease. Both the potential benefits to water supplies and the increased risk of flooding will no longer occur.

3.3.6 Impacts to Water Levels at the Sinks

The combined amount of mine dewatering water discharged to the Humboldt River would average 120,000 acre-feet per year during the predicted period of maximum cumulative discharges (1998 through 2006, see Figure 3-22). As can be seen in Figure 3-22, the predicted discharge volumes range considerably around this average. Depending on irrigation and other withdrawals along the river, between 15,000 to 60,000 acre-feet per year of mine dewatering discharges during the period may reach the Humboldt Sink. This is a general range that is highly dependent on irrigation withdrawals and return flows from year to year. (Uncertainties related to irrigation return flows are described in Section 3.1.3.1).

Based on average river gains and losses, average cumulative dewatering discharges, and general irrigation withdrawals and return-flow assumptions, approximately 18,000 acre-feet per year (11,000 gallons per minute) of mine dewatering water may reach the Humboldt Sink. Using the same input assumptions on a monthly basis, the additional volume ranges from 0 acre-feet per month in March through June to approximately 3,000 acre-feet per month in December. As a result of these estimated volume increases, greater water depths and areas of inundation could occur in the sink from additional water. In reality, the actual increases would vary substantially depending on rainfall, snowmelt, basin-wide user demands, and reservoir storage, and they may not occur at all. For example, approximately 60,000 acre-feet per year of dewatering discharge may reach the sinks if the excess water were not consumed upstream by irrigation or other demands on the river. In contrast, probably no additional water would reach the sink in drought years. It can be seen that the quantity and timing of climatic factors and non-mining water uses have a dominating effect on the overall river system. This is further illustrated in tables and figures presented in Appendix C.

It should be noted that the water reaching the sinks on an hourly or minute basis ranges even more widely from the estimates given above due to still wider variations in flows and water withdrawals at the smaller time intervals. For example, an average flow of 18,000 acre-feet per year (i.e., annually) would be composed of a series of much higher and lower flows when expressed in smaller time increments (e.g., gallons per minute). The reader must be careful not to confuse annual, seasonal, or monthly averages with steady-state (or constant) conditions as may be implied by an average expressed “per minute.” The variation of surface water flows with time and location is frequently a major factor in related impact assessments. Furthermore, although flow measurement units can be converted arithmetically to smaller time intervals, a corresponding increase in precision and accuracy should not be extrapolated by the reader.

For the Humboldt Sink, general estimates of evapotranspiration and occasional outflows to the Carson Sink are on the order of 110,000 acre-feet per year, including approximately 57,000 acre-feet passing the Lovelock gage on the river, approximately 43,000 acre-feet from irrigation returns, and 11,000-acre feet from direct rainfall. It is conceivable from these estimates that a large portion of the annual evapotranspiration losses from the Humboldt Sink may be accounted for by mine discharge contributions during the years of higher discharges, particularly if those years are "wet" years. As a result, the possibility exists for temporary effects in terms of greater water depths and areal extent at the Humboldt Sink and possible spillover into the Carson Sink. Spillover into the Carson Sink historically has been a natural periodic occurrence. Water depths in the Humboldt Sink, excess water disposal and evaporation, or additional spillovers to the Carson Sink may be able to be controlled through a system of dikes and gates that exist (or could be improved) at the southwestern end of the Humboldt Sink (Saake 1998). After the larger mine discharges cease (2006), flows to and from the Humboldt Sink will return to their historical conditions, which have varied from year to year.

3.3.7 Impacts to Humboldt River Surface Water Rights

It is not anticipated that the additional mine discharges would create long-term impacts to surface water rights within the Humboldt River Basin. Water resources within the basin have been over-appropriated historically, and the temporary nature of the discharges is not likely to affect that situation. It is possible that more existing rights may be fulfilled to varying degrees during the period of mine discharges. This would be a beneficial impact during the discharge duration. The amounts, locations, and timing of these further fulfillments would vary considerably depending on the seniority of rights and the volume of discharge. The further uses of water would depend largely on the existing agricultural infrastructure and future marketplace demands.

After the cessation of mining discharges, a gradual decrease in low flows (followed by a gradual recovery) may create a potential seasonal impact on late-season irrigators or aquatic habitat. Smaller water volumes and lower water surface elevations could create seasonal shortages or other physical limitations to diversions or habitats during the later part of the growing season. Below Palisade, irrigation water withdrawals based on decreed rights may be made through September 15. Some older permitted rights may allow withdrawals after that date.

As discussed in Section 3.3.2, flows in the latter part of the irrigation season may be affected by ground water drawdown. The flow decreases would be most noticeable during the late summer and early fall. The largest decreases relative to monthly average flows would occur in September and October after most irrigation under the decrees has ceased, but noticeable effects could occur earlier. As explained in Section 3.3.2, on a yearly basis the maximum decrease would be approximately 3 percent of the average annual flow, and this is predicted for the years 2016 through 2019. Before and after this period, the decrease in the average annual flow is predicted to be approximately 1 percent, and to be gradually restored to historic conditions over a period of decades (HCI 1997a). The impact of this on other water users in the basin depends on their demands (see Table C-1, Appendix C) and the occurrence of wet or dry years.

As discussed in Section 3.3.1.3, Newmont has committed to augmenting low flows in the river, using senior water rights that the company owns or controls (BLM 1993b). These activities would mitigate the potential for impacts to junior water rights holders.

3.3.8 Impacts to Water Quality

3.3.8.1 Background

Cumulative discharges associated with mine dewatering could potentially affect water quality in the Humboldt River and Humboldt Sink. There are several water quality related issues associated with the mine discharges. These issues include potential increases in concentrations and loadings of inorganic constituents in the river and at the Humboldt Sink. All existing mine discharges operate in compliance with the provisions of the Clean Water Act, as administered by the Nevada Bureau of Water Pollution Control. The mines are authorized to discharge under the provisions of their respective NPDES permits that contain effluent limitations and monitoring and reporting requirements. The effluent limitations are designed such that water quality constituent concentrations will not exceed stream water quality standards established for the protection of identified beneficial uses.

3.3.8.2 Impacts to Date

In general, mine discharges have historically been within their permit limitations (no significant non-compliance) and support the assumption that future mine discharges would not impact water quality in the river. Significant non-compliance of an NPDES permit is defined by criteria that include 1) exceedence of a 30-day average limit any 4 out of 6 months, 2) exceedence of a 30-day average limit by a factor of 1.4 or greater for any 2 out of 6 months, or 3) judgement of significant impact to human health or the environment by Nevada Bureau of Water Pollution Control Staff (Livak 1999). Only one significant non-compliance violation has been documented under the current NPDES operating permits. Discharges from the Lone Tree Mine were in significant non-compliance for arsenic in early 1995, but treatment and dewatering systems were adjusted to correct the NPDES permit exceedence (Livak 1999).

3.3.8.3 Projected Future Impacts

It is assumed that any projected future discharge from the existing and proposed mines would be within the requirements of their respective NPDES permit limitations. Therefore, provided that all of the mine discharges operate in accordance with their permit limitations, cumulative impacts to water quality in the river are not anticipated.

Potential Loading of Inorganic Constituents

Even though the historic and projected future mine discharges are anticipated to be within their permit limitations, there is concern that the cumulative mine discharge would contribute additional loads of inorganic constituents to the Humboldt Sink. If the cumulative mine discharge significantly increased the loads of inorganic constituents to the sink, these loads would potentially be available through evapoconcentration processes to increase concentrations in the sink.

As stated in Section 3.2, Affected Environment, the water quality of the Humboldt Sink wetland areas has been studied and monitored on an intermittent basis since 1987 jointly by the USGS and USFWS (Rowe et al. 1991; Seiler et al. 1993; Seiler and Tuttle 1997). The studies concluded that arsenic, boron, mercury, molybdenum, sodium, un-ionized ammonia, selenium, and dissolved solids exceeded biological effects levels or Nevada standards for the protection of aquatic life. Causes of contamination were identified as irrigation drainage, hydrogeologic setting, historic mining activities, and drought (Seiler and Tuttle 1997).

Approach. By measuring both the concentration of a chemical constituent in water and the associated flow rate or volume, the amount of the chemical constituent transported during a fixed time interval (or load) can be calculated. Units of load are typically provided in pounds per day or tons per year. These calculations were performed to estimate the premine loads in the river and the additional loads added to the river from the cumulative mine discharge. The estimated increased load from the mines was then compared to premine conditions at various points along the river and at the sink. It is important to understand that the loads from the mines represent a maximum load that could be transported to the sink. For certain constituents (such as heavy metals), the actual load transported to the sink would likely be less than the initial loads delivered to the river at the discharge points, since some of the load would be removed during transport due to adsorption or precipitation. For other more mobile constituents, the calculated loads from the mines represent loads that are less likely to be removed during transport to the sink.

Estimates of mine discharges to the Humboldt River for this loading analysis were based on actual historic discharges for the 1991 through 1998 period and estimated future mine discharges for the post-1998 period. RTi (1998) provided an estimate of potential future discharges from each of the mines based on information provided by Barrick and Newmont. In 1999, Barrick and Newmont provided revised estimates of future mine discharges to the Humboldt for the Goldstrike, Gold Quarry, Leeville, and Lone Tree mines (Barrick 1999b, 1999c; Newmont 1999a and 1999b). Compared to the earlier estimates (RTi 1998), the revised estimates indicate that: 1) the Goldstrike Mine would no longer discharge to the Humboldt River after the first quarter 1999 (earlier estimates assumed Goldstrike would discharge from 1999 through 2011); 2) the average annual discharge from Gold Quarry would be as high as 24 percent greater but the period of discharge (1999-2011) would be unchanged; 3) Leeville would discharge at a similar range of rates but for 4 years instead of 19 years; and 4) Lone Tree would discharge for the same period and at similar average rates. The reduction in discharge and change in discharge periods for the Goldstrike and Leeville mines reflects that under the updated water management plans, a larger percentage of the excess mine water would be reinfiltrated or consumed by crop production within the Boulder Valley Hydrographic Area. Revisions to estimates for Gold Quarry are based on the revised estimates of dewatering requirements for the proposed SOAPA (HCI 1999b). Overall, the most recent estimates represent a reduction in total future discharge (1999-2018) of approximately 16 percent compared to earlier estimates. For the purposes of estimating potential load to the Humboldt River and the sink, this analysis used the slightly higher discharge scenario based on the information provided in RTi (1998). This discharge scenario is considered to be environmentally conservative since it accounts for a higher cumulative discharge volume over time and correspondingly higher loads. Although unlikely, it should be understood that if the mines discharged at higher rates than anticipated or at the maximum rates allowed by their respective discharge permits over extended periods, the actual cumulative volume of water delivered to the river system and the corresponding loads would be greater than projected in this evaluation.

Constituents of Concern. The USFWS has identified several constituents of concern for this cumulative assessment. The constituents of concern include arsenic, boron, chromium, copper, fluoride, lithium, manganese, mercury, molybdenum, selenium, thallium, uranium, zinc, and total dissolved solids (TDS). Available water chemistry data from the mines were reviewed to determine if there was representative information from which to calculate loads. Based on available data, representative loads were calculated for arsenic, boron, copper, fluoride, zinc, and TDS. There were insufficient data to calculate a cumulative load for lithium, manganese, molybdenum, sodium, thallium, and uranium. In addition, meaningful loads for chromium, mercury, and selenium could not be calculated because for the majority of the water quality analyses for the mines, concentrations of these constituents were reported to be below the detection limit. For chromium, mercury, and selenium, the majority of the water quality analyses for the Humboldt River were also below detection. As presented in Table 3-25, chromium, mercury, and selenium concentrations were generally at or below the detection limit in the river at Carlin and Rye Patch, and also at the point of discharge into the sink. These data suggest that the concentration of chromium, mercury, and selenium do not increase substantially from Carlin to the sink. For arsenic, boron, copper, fluoride, zinc and TDS, there was sufficient information, and the majority of the samples used to calculate average concentration for the mine discharge were above the detection limits.

Database. Available water quality information was compiled for the Humboldt River for all stations located between Carlin and the Humboldt Sink. For determining premine conditions, only samples for which both water quality and instantaneous river flow were measured at the time of sampling were considered. Water quality data are available for most of the gage sites shown in Figure 1-1. The most representative information on premine water quality in the Humboldt River exists for the Carlin gage for the April 1979 through April 1991 period, and at the Rye Patch gage for the October 1974 through July 1986 period (see Figure 1-1). Data from other water quality stations were much less complete and were not considered in this evaluation. The Carlin site was selected for evaluation since it represents conditions in the upstream reach of the Humboldt River study area. The Rye Patch site was selected to represent conditions in the lower portion of the river immediately above the Lovelock agricultural development. Below the Rye Patch gage, a large percentage of river flows are diverted for irrigation. The Humboldt River and the Army Drain are the primary sources of flow to Humboldt Lake; the Toulon Drain is the primary source of flow to Toulon Lake. Only a few samples are available to define the load for each of these three sources of flow to the Humboldt Sink (Humboldt River immediately above the sink, Army Drain and Toulon Drain) for the premine discharge period (prior to 1992). Because of the limited data, actual premine discharge load to the sink cannot be quantified. However, the data were used to qualitatively describe the relative potential increases in loads to the sink from the cumulative mine discharge.

Representative water quality data from recent discharge periods were used to estimate the average concentrations for each constituent used in this evaluation for the Goldstrike, Gold Quarry, and Lone Tree mines. For the proposed Leeville Mine, the discharge water quality was estimated using water quality analyses from the weighted average of the concentrations detected in test wells (Maxim 1998). The wells were weighted to reflect the estimated percent contribution of ground water from each identified hydrolithologic zone. The calculated average concentrations were then assumed to approximate the average concentration of the mine discharge. For the purposes of this analysis, it is assumed that the average concentrations provide a reasonable estimate of future discharge water quality.

Arsenic, boron, copper, fluoride, zinc, and TDS loads in the Humboldt River at the Carlin and Rye Patch sites and above the sink were calculated using dissolved constituent concentrations. Constituent concentrations used for the mine discharges are reported as either dissolved, total recoverable, or total. For this evaluation, calculated mine discharge loads were assumed to be dissolved loads and were compared directly to dissolved loads calculated in the Humboldt River. This assumption is reasonable since ground water discharges similar to the mine dewatering flow are typically dominated by the dissolved fraction of constituents. In addition, since total recoverable and total loads include the dissolved fraction, the loads

Table 3-25
Humboldt River and Humboldt Sink Trace Element Measurement Summary for Dissolved Chromium, Mercury, and Selenium

Constituent	Units	n	ND	Average	Minimum	Maximum	Period
Chromium							
Humboldt River[1]							
Carlin	µg/L	48	37	1.14	<1.00	7.00	5/79 – 4/91
Rye Patch	µg/L	43	35	1.98	<1.00	20.0	1/75 – 9/86
Sink Inflows [2]							
Humboldt River near Lovelock	µg/L	5	3	<1.00	<1.00	1.00	8/88 – 11/90
Toulon Drain	µg/L	5	2	1.06	<1.00	2.00	8/88 – 5/96
Army Drain	µg/L	5	3	1.10	<1.00	2.00	8/88 – 11/90
Mercury							
Humboldt River[1]							
Carlin	µg/L	49	40	<0.100	<0.100	0.500	5/79 – 4/91
Rye Patch	µg/L	43	28	0.173	<0.100	1.80	1/75 – 9/86
Sink Inflows [2]							
Humboldt River near Lovelock	µg/L	6	5	<0.100	<0.100	0.100	10/87 – 11/90
Toulon Drain	µg/L	6	5	<0.100	<0.100	0.100	10/87 – 5/96
Army Drain	µg/L	6	4	0.142	<0.100	0.500	10/87 – 11/90
Selenium							
Humboldt River[1]							
Carlin	µg/L	49	46	<1.00	<1.00	1.00	5/79 – 4/91
Rye Patch	µg/L	43	14	<1.00	<1.00	1.00	1/75 – 9/86
Sink Inflows [2]							
Humboldt River near Lovelock	µg/L	6	5	<1.00	<1.00	1.00	10/87 – 11/90
Toulon Drain	µg/L	6	3	<1.00	<1.00	2.00	10/87 – 5/96
Army Drain	µg/L	6	3	<1.00	<1.00	2.00	10/87 – 11/90

n = number of concentration results available with corresponding instantaneous flow data.

ND = non-detectable.

Average = calculated average of available results (calculations used one-half the detection limit for non-detected values; if calculated average was less than detection limit, result was reported as less than the detection limit).

Minimum = lowest value of available results.

Maximum = highest value of available results.

Period = time period containing available results.

[1]Data source: USGS data from gage 10321000 (Carlin) and gage 10335000 (Rye Patch).

[2]Data source: Seiler and Tuttle 1996.

calculated for the mine discharges are considered to be reasonable and conservative when compared to the dissolved loads calculated for the river.

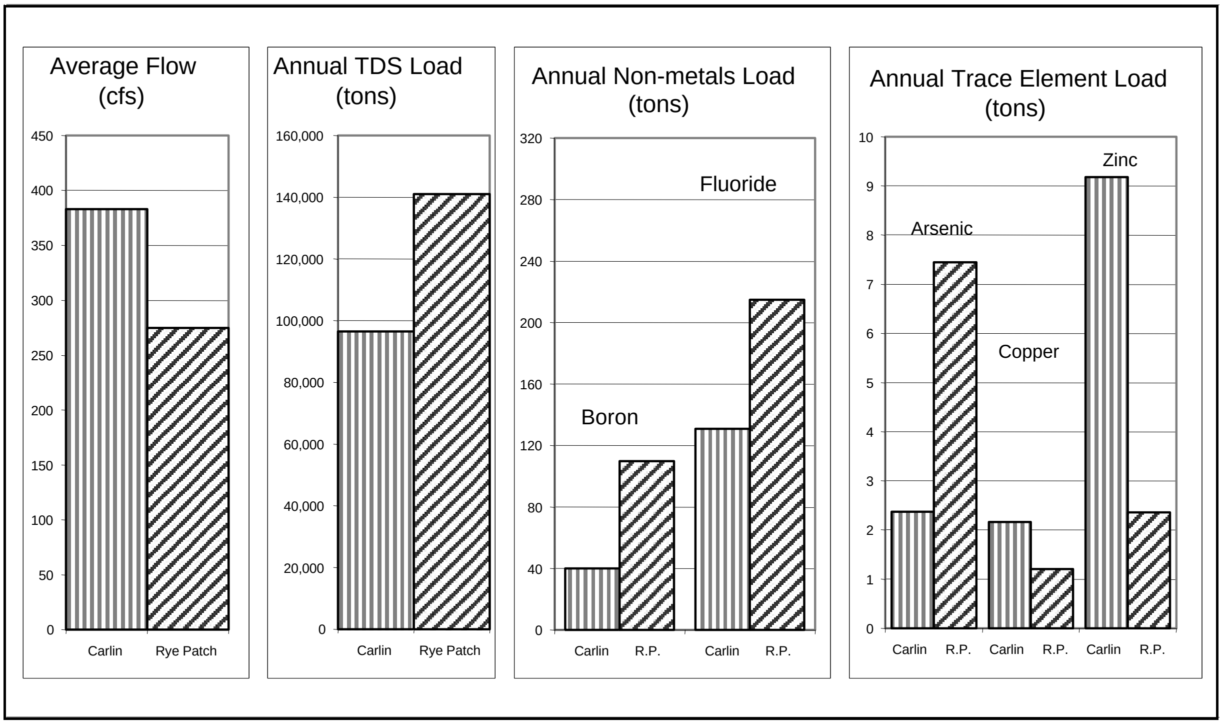
In some cases, the water quality database used to estimate the premine loads in the river and the additional loads contributed by the mines contained constituent concentrations both above and below the detection limit. For concentrations reported to be below detection, a value of one-half the detection limit was used.

Premine Loading in the Humboldt River. Loads for TDS and dissolved arsenic, boron, copper, fluoride, and zinc in the Humboldt River prior to mining discharge were evaluated at Carlin (above the mining area) and near Rye Patch (downstream of the mining area and upstream from the Humboldt Sink). As can be seen in Figure 3-25, there is a significant decrease in fow downstream between Carlin and Rye Patch. Between Carlin and Rye Patch there is an increase in TDS and dissolved boron, fluoride, and arsenic loads and a decrease in dissolved copper and zinc loads.

Increases in TDS and dissolved arsenic, boron, and fluoride loads are likely the result of sources providing additional loads to the river section. Fluoride and most of the elements that influence TDS loads are also likely to be very mobile (not readily removed from the water column by mechanisms such as adsorption or precipitation) in relatively dilute concentrations such as those measured in the Humboldt River. Therefore, dissolved loads of these parameters entering the river flow would most likely be transported to the sink. In well-oxygenated waters, such as the Humboldt River from Carlin to Rye Patch, dissolved arsenic and boron generally form negatively charged oxides (Hem 1992; Drever 1997). These oxides also tend to be relatively mobile and would likely be transported to the sink. Decreases measured in dissolved copper and zinc loads between Carlin and Rye Patch (Figure 3-25) could be the result of adsorption or precipitation reactions removing these parameters from the Humboldt River flows. At neutral pH values, such as those measured in the river, metals such as these tend to form solid precipitates or adsorb onto suspended and sediment particles (Drever 1997; Hart and Hines 1995). Precipitates and suspended particles may then settle out of the water column reducing the total metals load transported by the river. Figure 3-25 illustrates that only a fraction of the dissolved heavy metal loads introduced to the Humboldt River are likely to travel to the sink.

Potential Increases in Dissolved Loads from Mine Discharges at Rye Patch. The Rye Patch gage is located downstream of all mine discharges and upstream of the sink. The average annual loads calculated for the Rye Patch gage were used as a frame of reference to evaluate potential total dissolved load from the mining discharges. The potential total dissolved load was calculated by adding the mine loads to the average annual dissolved load calculated for the river. These are assumed to be maximum loads that could potentially be transported to the Rye Patch gage. While this may be a reasonable assumption for TDS, arsenic, boron and fluoride, it likely overestimates the amount of dissolved copper and zinc that would be transported due to the processes previously described.

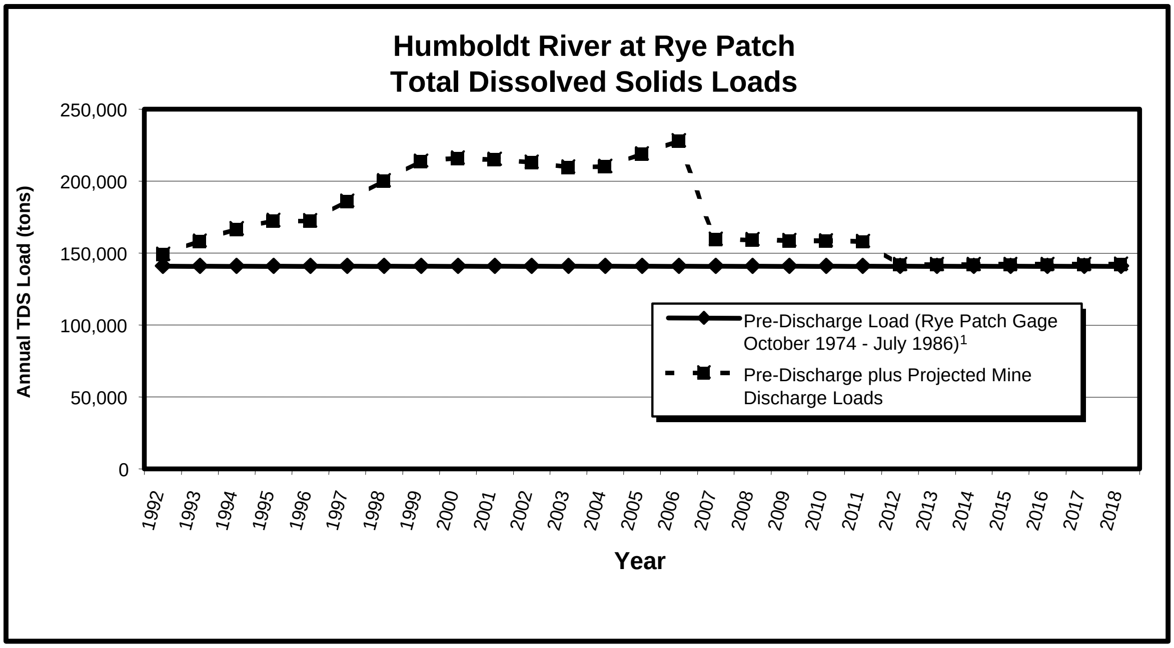
As shown in Figures 3-26 and 3-27, on an average annual basis, the mine discharges represent a substantial loading increase in TDS, arsenic, boron, and fluoride compared with premine discharge conditions at the Rye Patch gage. For the purposes of discussion, all potential increases in loads are discussed in terms of the relative percent increase over average annual premining dissolved loads. TDS shows a gradual increase in 1992 of approximately 6 percent rising to a maximum increase of 62 percent in

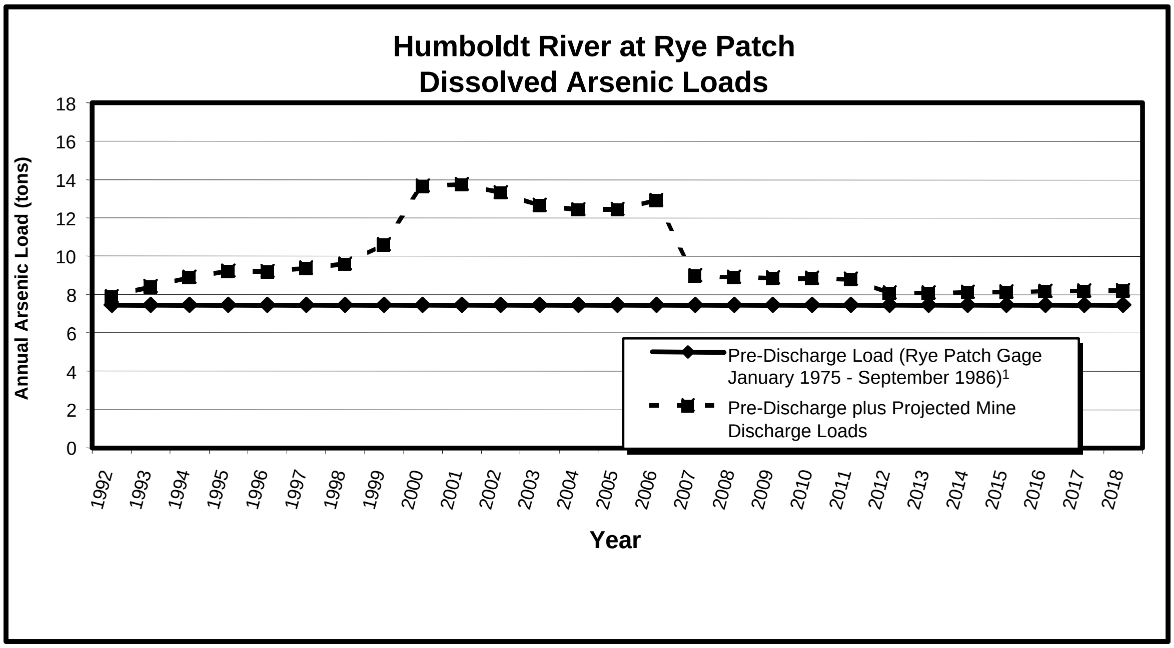


Comparison of the estimated average annual dissolved load transported by the Humboldt River at the Carlin and Rye Patch gages prior to mine discharges.

Figure 3-25

Estimated Average Annual Premine Loads at the Carlin and Rye Patch Gages



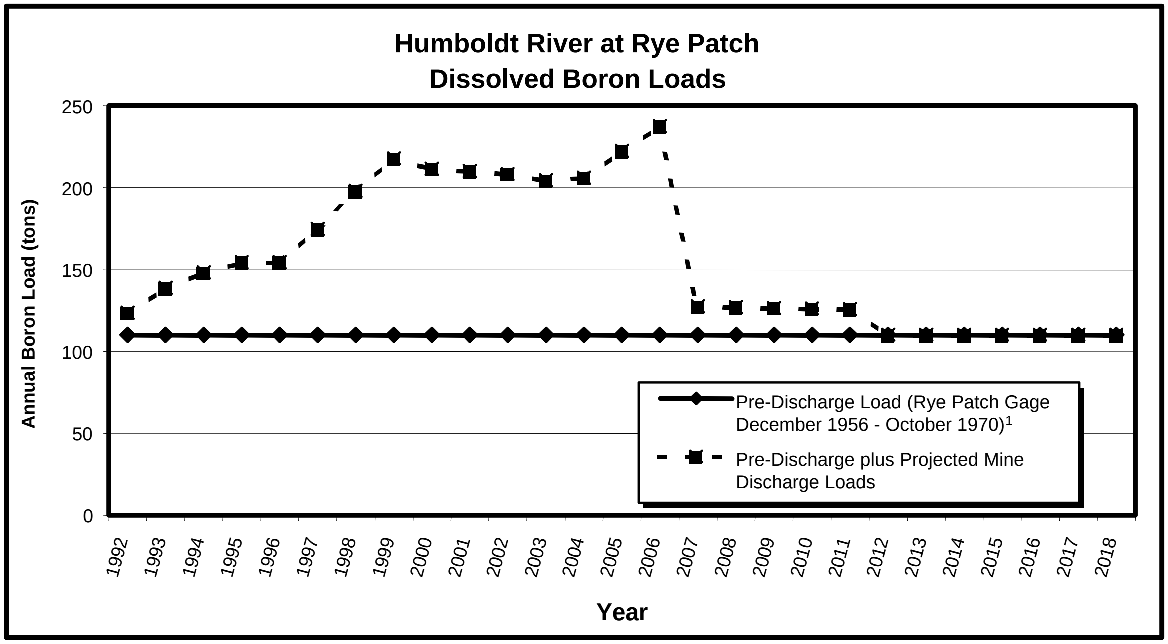


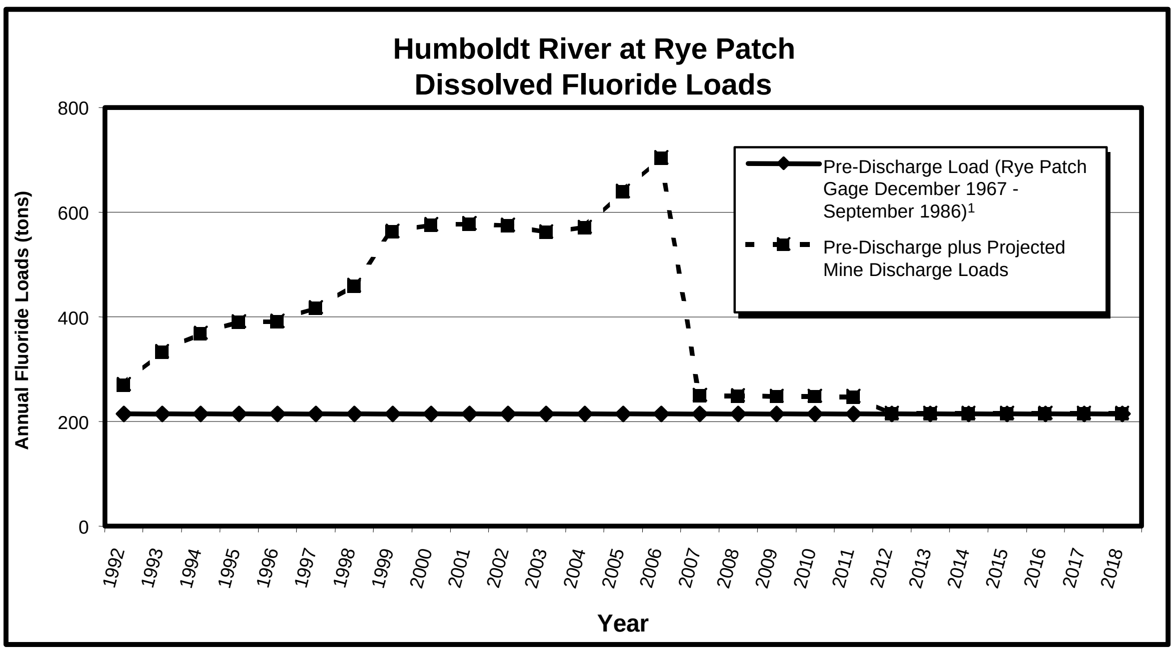
Potential maximum increases in annual loads of TDS and dissolved arsenic resulting from the combined mine discharges at the Rye Patch gage over the mine discharge period.

[1] Assumes that the average annual pre-discharge loads, or baseline loads, carried by the river remain constant over the mine discharge period.

Figure 3-26

Potential Maximum Increases in Annual Loads of TDS and Arsenic at the Rye Patch Gage





Potential maximum increases in annual dissolved loads of boron and fluoride resulting from mine discharges at the Rye Patch gage over the mine discharge period.

[1] Assumes that the average annual pre-discharge loads, or baseline loads, carried by the river remain constant over the mine discharge period.

Figure 3-27

Potential Maximum Increases in Annual Loads of Boron and Fluoride at the Rye Patch Gage the year 2006, and then dropping to negligible levels after 2011. Arsenic shows a potential increase of up to 85 percent in year 2001; drops off to the 18 to 21 percent range between 2007 and 2011; and decreases to between 9 to 11 percent after 2011. Boron and fluoride loads show similar trends through the mine discharge period, with peak increases of 116 percent for boron and 228 percent for fluoride in year 2006, and then dramatic decreases to less than 20 percent by 2007.

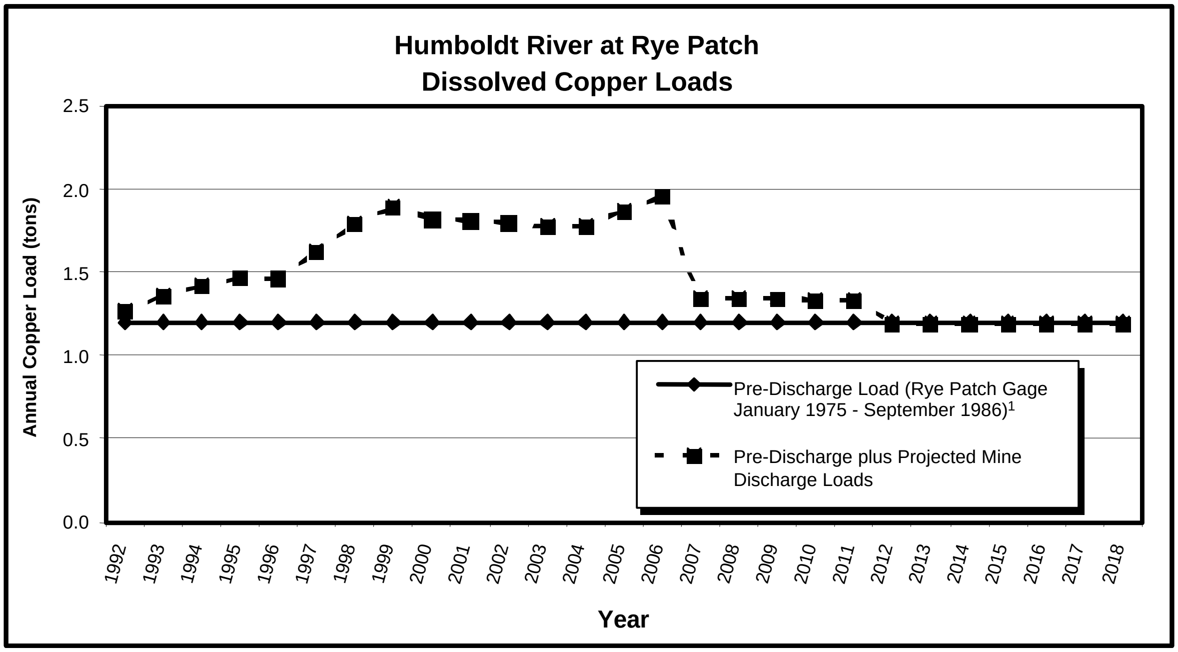
As shown in Figure 3-28, dissolved copper and zinc loads show slightly different loading patterns with copper gradually increasing from 1992 to 1999, and then holding at a peak level of between 50 percent and 63 percent increased loads from 1999 through 2006. After 2006, the potential increase in copper loads is less than 13 percent. Zinc loads increase from 1992 to 2000 and remain at a maximum increase load ranging from an increase of 60 to 67 percent from 2000 to 2006. From 2007 to 2011, the zinc loads represent an increase of approximately 40 to 42 percent, and become negligible after 2011. As described previously, loads from copper and zinc (and other heavy metals) would likely decrease during transport due to precipitation and adsorption processes. Therefore, actual increases in dissolved copper and zinc loads observed at the Rye Patch gage are anticipated to be less than the loads discharged by the mines.

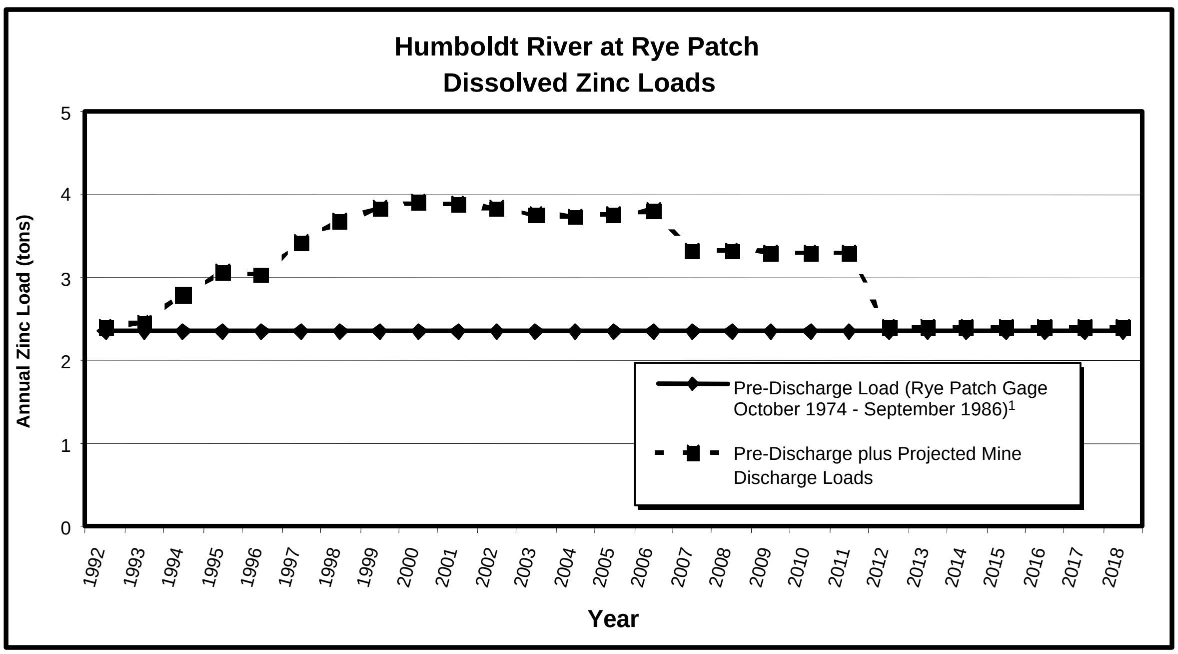
The total potential increases in loads from mine discharges were evaluated for the 27-year discharge period (1992 – 2018) using the procedure described above. As illustrated in Figure 3-29, the mine discharges over the 27-year discharge represent a potential increase of 24 percent for TDS, 33 percent for arsenic, 42 percent for boron, 75 percent for fluoride, 24 percent for copper, and 34 percent for zinc. With the exception of the metals (copper and zinc) these potential increases to loads at the Rye Patch gage represent dissolved loads that could potentially reach the Humboldt Sink.

Potential Increases in Loads from Mine Discharge to the Sink. Between the Rye Patch gage and the Humboldt Sink, a large percentage of the Humboldt River flows are diverted and routed through the Lovelock agricultural area. This diversion and return flow system includes approximately 50 miles of main canals, 100 miles of lateral drains, and 130 miles of open return channels (Seiler et al. 1993). Discharge from the agricultural drains is one of the primary sources of water to the sink. Discharge water from the drains contains concentrations of TDS, arsenic, boron, mercury, molybdenum, sodium, un-ionized ammonia; these concentrations possibly exceed biological effects levels or Nevada standards for the protection of aquatic life (Seiler et al. 1993). The agricultural discharge results in a substantial increase in loads between the Rye Patch gage and the terminal wetlands at the sink.

The Humboldt Sink wetlands are part of the wildlife management area. The wetlands include Toulon Lake and Humboldt Lake. The primary source of water for Toulon Lake is the Toulon Drain. The principal sources of water for Humboldt Lake discharge from the Army Drain and the Humboldt River. Actual discharges to the sink are not known since discharges from the drains and the lower Humboldt River are not monitored on a regular basis. In addition, water quality data for the drains and the Humboldt River are limited.

Streamflow records for the lower Humboldt River exist for the period from 1950 to 1959. Using these limited monitoring records, the average annual discharge to the sink from the river was estimated to be approximately 57,000 acre-feet with an additional 42,000 acre feet discharged from agricultural return flows. A few water quality samples were taken between 1987 and 1990 at the Toulon Drain, Army Drain, and the



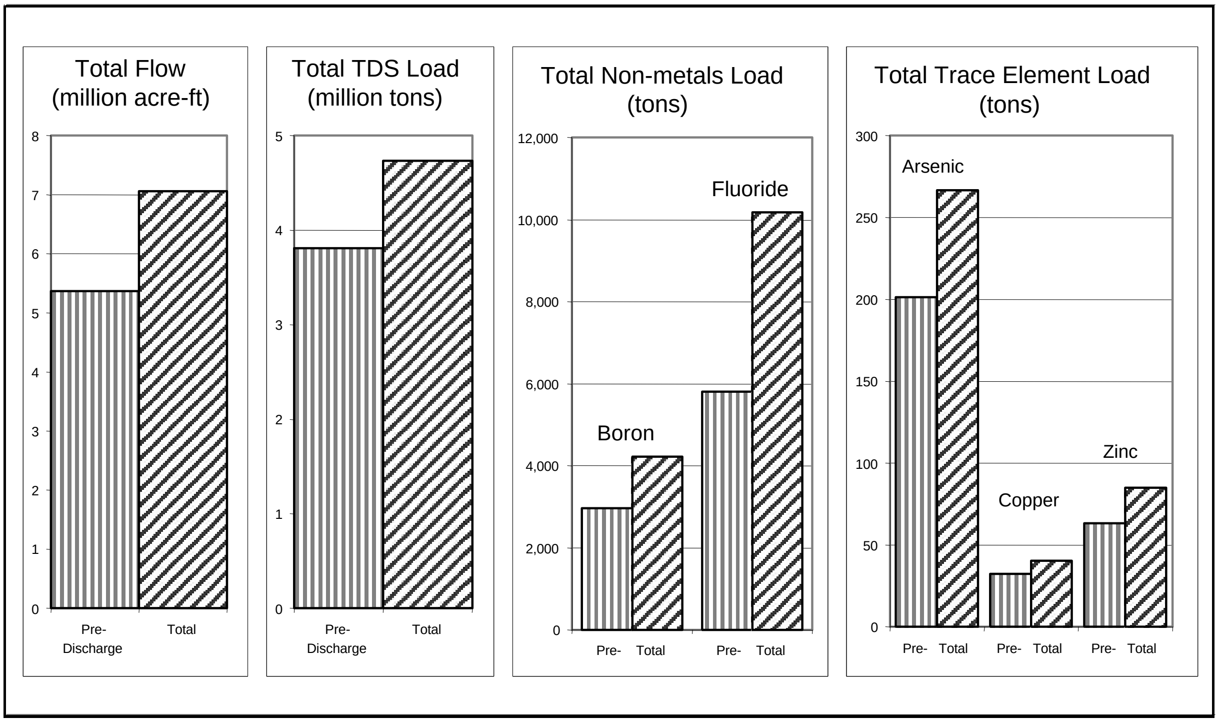


Potential maximum increases in annual dissolved loads of copper and zinc resulting from mine discharges at the Rye Patch gage over the mine discharge period.

[1] Assumes that the average annual pre-discharge loads, or baseline loads, carried by the river remain constant over the mine discharge period.

Figure 3-28

Potential Maximum Increases in Annual Loads of Copper and Zinc at the Rye Patch Gage



Comparison of the dissolved loads without mine discharge contribution (vertical fill) with the total post mine discharge loads (slashed fill) over the entire historic and projected future discharge period (1992-2018) at the Rye Patch gage.[1]

[1] Assumes that the average annual pre-discharge loads, or baseline loads, carried by the river remain constant over the mine discharge period.

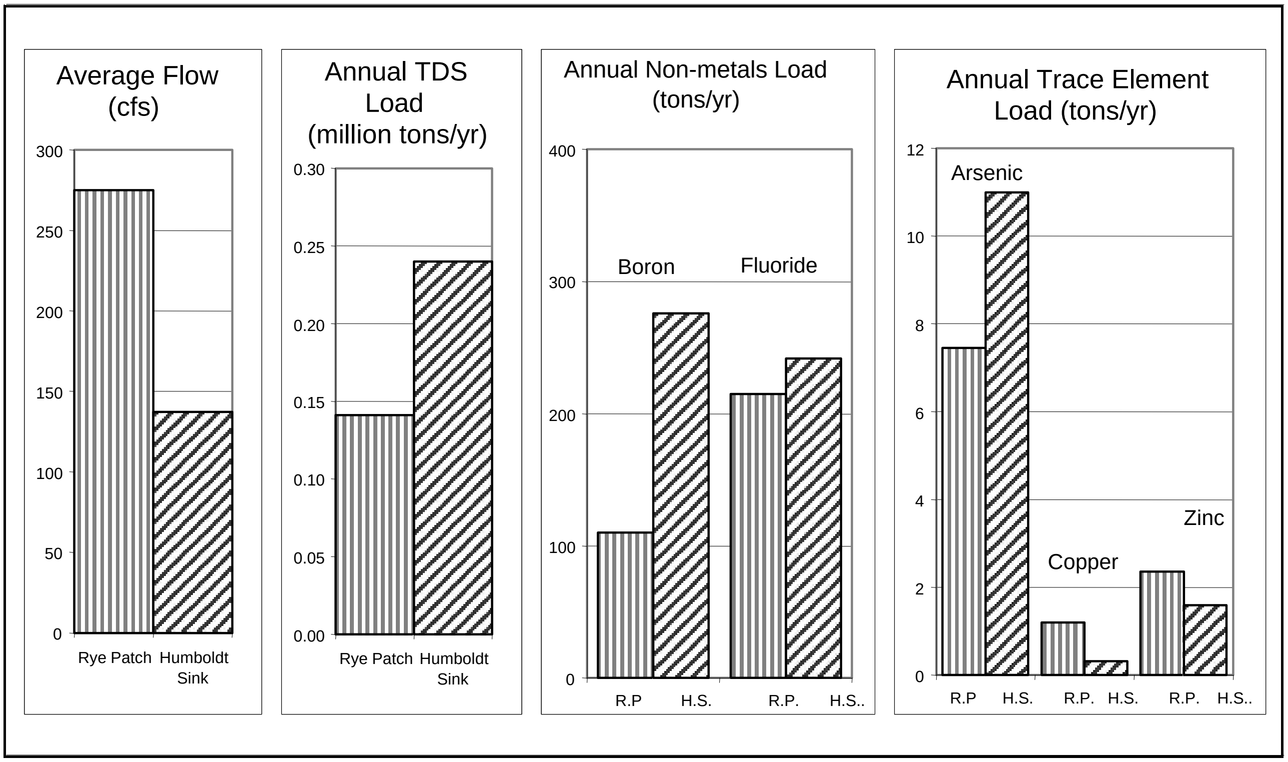
Figure 3-29

Total Potential Increase in Loads During the Mine Discharge Period (1992-2018) at Rye Patch Gage

Humboldt River at Lovelock. These data were used to calculate a preliminary estimate of the premine loads entering the sink wetlands. The potential mine loads were then added to the estimated premine loads entering the sink, to provide a preliminary evaluation of potential increases in loads to the sink. The results of this evaluation of the sink are presented in Figure 3-30. Due to limited data and simplifying assumptions, this evaluation should be viewed as a very rough approximation. The estimated loads are presented to provide a reference for evaluating the relative magnitude of change in loads represented by the combined mine discharges.

Figure 3-30 presents a comparison of the estimated average annual dissolved loads transported by the Humboldt River at the Rye Patch gage with the estimated average annual dissolved loads discharged to the Humboldt Sink (represented by the combined loads calculated for the Humboldt River near Lovelock, Toulon Drain, and Army Drain). Based on the available data, and the assumptions for discharge to the sink, as illustrated in Figure 3-30, there appears to be a major increase in TDS and dissolved boron and arsenic loads between the Rye Patch gage and the point of discharge into the Humboldt Sink. This plot also suggests that dissolved fluoride loads do not increase substantially, and dissolved copper and zinc loads actually decrease between Rye Patch and the sink. Since the background loads for TDS, boron, and arsenic were much higher in the drains and lower Humboldt River prior to mine discharge, the potential increase in dissolved load (as a percentage of background) resulting from the mine discharge is anticipated to be much less at the sink than at the Rye Patch gage (Figure 3-31). Potential increases in dissolved fluoride loads are similar to the increases discussed for Rye Patch. Substantial increases in dissolved copper and zinc loads generally are not anticipated since there is a general decrease in metal loads from Carlin to Rye Patch, and then to the sink. This suggests that precipitation and adsorption processes during transport would likely remove a substantial percentage of the dissolved metals load.

In conclusion, the cumulative loads from the mine discharges would likely increase TDS and dissolved arsenic, boron, and fluoride loads to the sink over the mine discharge period. The relative magnitudes of these potential increases are illustrated in Figure 3-31. Depending on concentrations in the sink, parameter solubilities, and other physical and biological factors, increased loads to the sink could potentially result in increased concentrations in the sink wetlands. However, similar to periods prior to mine discharges, the amount of surface water stored in the sink at any one point and the amount of flow received by the sink wetlands appear to be the primary controlling factors for constituent concentrations in the wetlands.

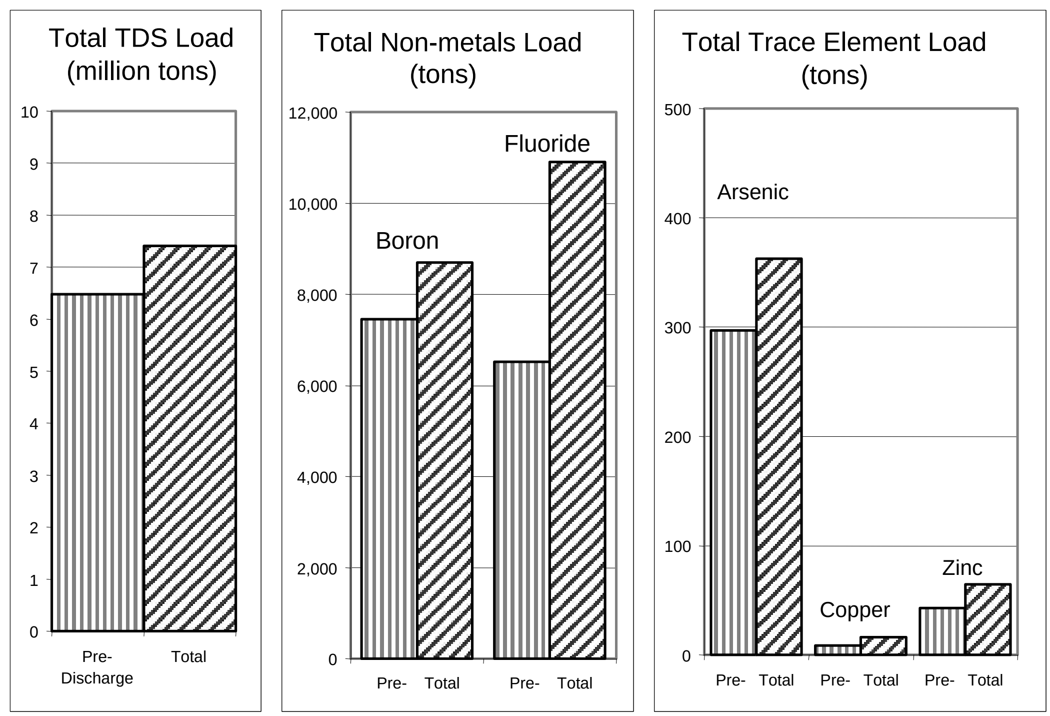


Comparison of the estimated average annual dissolved load transported by the Humboldt River at the Rye Patch gage with dissolved load discharge to the Humboldt Sink (Humboldt River near Lovelock, Toulon Drain, and Army Drain).[1] Note that estimated loads discharged to the sink are based on very limited flow and water quality data.

[1] Assumes that the average annual pre-discharge loads, or baseline loads, carried by the river remain constant over the mine discharge period.

Figure 3-30

Comparison of Average Annual Loads at Rye Patch Gage vs. Humboldt Sink (Premine Discharge)



Comparison of the dissolved loads without any mine discharge contribution (vertical fill) with potential total dissolved loads during the discharge period (slashed fill) over the entire historic and projected future discharge period (1992-2018) to the Humboldt Sink.[1] Note that 1) estimates of loads to the sink are based on limited premine data; and 2) actual mine contributed loads reaching the sink could be less than total potential (see text for additional explanation).

[1] Assumes that the average annual pre-discharge loads, or baseline loads, carried by the river remain constant over the mine discharge period.

Figure 3-31

Total Potential Increase in Loads During the Mine Discharge Period at the Humboldt Sink